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(1) Make your paper as concise as possible. As the *Journal* appears only twice a year, space is at a premium.

(2) On the first page, start typing at least three inches down from the top. It is convenient to have title, author's name and institution, and a brief informative abstract, all on the first page.

(3) Follow the format of papers published in recent issues of the *Journal*.

(4) Double-space *everything*—abstract, text, tables, quotations, reference list.

(5) *Type* simple tables, such as lists; they will be set in print. *Draft and letter* complicated tables, involving ruled spaces, special symbols, etc.; they will be reproduced photographically.

(6) Include line drawings only if essential to your subject. Photographs are ordinarily not acceptable.

Journal of Geological Education

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GEOLOGICAL PERSPECTIVE*

CAREY CRONEIS
Rice University

The title of this address is presumptuous. So is its substance. They are presumptuous first because I obviously do not have the competence to discuss the subject in more than a very few of its many ramifications, and second because, in such a meeting as this, I am certainly a novice among sophisticates in many of the disciplines on which we shall touch. Moreover, this is only a review; but I do not apologize because reviews commonly engender thoughts that original articles fail to father. I do not even apologize for the fact that this paper is, in part, a condensation of a lecture I prepared for the A.G.I. Visiting Scientist Program. Indeed I may wryly observe that there are other papers on this G.S.A. program whose abstracts also have a faintly familiar ring.

The English geologist, Herbert Hawkins, some twenty years ago said:

> The history of the decline and fall of empires makes familiar reading for a paleontologist; it illustrates in a condensed and diagrammatic form the late phases of evolution in other creatures. . . Regrettable though it may be, the human animal seems . . . superior to a dinosaur . . . merely in the speed that it rushes toward extinction.

Even though the Age of Fission is now reaching its majority, and the Space Age is dawning, most of us are no more—and no less—pessimistic now than Hawkins was in 1938. It is apparent, however, in spite of—or more properly because of—all the present preoccupation with the rat race of rocketry and the sweepstakes of extra-terrestrial engineering, that, in the light of geological and geobiological history, we could, with considerable profit, accelerate our philosophical studies of Mankind and his earthly abode. Scientifically, these interrelated subjects still fall within the realm of Terra Incognita—or in the domain of Geology in its broad and proper sense. At any event, they are certainly topics of general interest and public concern on which any normally intelligent scholar's opinion may well be as good as another's, and possibly better.

Indeed, contradictory speculations on man, his present problems and future possibilities, are legion. And one of the troubles that few scientists or philosophers have been able to avoid, in trying to look dispassionately at Mankind, is this: the

*Presidential address, National Association of Geology Teachers, presented at Denver, November 2, 1960.

tendency to hold in considerable, if not equal, esteem the commonly contradictory pronouncements of the religious leaders of the past and the scientific leaders of the present. And, since Sputnik I, it has become obvious to all that even the wildest scientific speculation or prediction should at least command sufficient respect to engender further critical study. This is one of several reasons why the teacher of beginning geology—or advanced geology, for that matter—should, I think, give widely ranging philosophical reviews as often as possible without upsetting normal class routine and progress.

For example, let us speculate on the implications of the thesis that the world is on the verge of running out of the *conventional* geological sources of energy. If this projection is sound, what does it mean for man? What does it signify for future geologists?

The scarcity thesis is not new—and with our present, temporary glut of oil it is a little out of style. Parenthetically, the oil companies will likely be scrambling for well-trained geologists by 1965, and desperate for them by 1968. But it is a certainty, rather than a prophecy, that our energy requirements next century will reach "impossible" levels. This will result from a set of irresistible, complementary, and mutually augmenting forces. These include explosive population growth, the insatiable demand for so-called higher living standards, and the steeply ascending curves marking the rates of industrialization and scientific progress.

The skeletal facts on this particular point in our discussion scarcely need reviewing. The present world population is at least 2.8 billion. It is also reasonably definite that the global population in 1860 was not much more than one billion. Thus, roughly speaking, the world population has more than doubled during the past century.

Energy requirements for industrialization, however, are increasing even faster than population. At present, world energy consumption is at least 0.1 times 10^{18} British thermal units. Should world population triple during the next century, and the present rate of per capita increase in energy requirements hold, the world's energy needs will have increased by well over 2000 percent by the year 2060.

But probably even such a figure is too conservative, because new industries—such, for example, as those concerned with processing sea water for minerals, refining of rocks now far below commercial grade, converting salt water to fresh, and air conditioning much of the civilized world, not to mention the energy requirements of the conquest of outer space—should further increase the world's total energy needs from ten to one hundred fold. Geologists should not stand idly aside and watch these developments grow solely under the aegis of other scientists.

Many students of the subject believe that it may be almost impossible to meet the top energy-requirement figure of 10 times 10^{18} B.t.u. by "conventional" methods. The total energy available from all fossil fuels, recoverable at even twice the present cost, is generally considered to be only about 21 times 10^{18} B.t.u., and only one-fourth of this total is in the form of oil and gas.

Thus, although for at least a generation more and more geological know-how will be required to discover and develop the fossil fuels, the dependence on such fuels will surely begin to diminish sometime in the century ahead—and *in time*

there will be a diminution of demand for geologists—at least for their present-day orthodox tasks with reference to oil, gas, and coal.

How about the world reserves of uranium and thorium? Assuming good recovery and efficient fuel-breeding methods, they are generally considered to amount only to some 500-600 times 10^{18} B.t.u. If, as we believe, such informed guesses are substantially correct, we may have not much more than a century of supply even from this recently proved, practical energy source—that is, at the rate of energy demand predicted for 2060. Power from fission, moreover, involves the problem of disposal of radioactive wastes. This problem is generally recognized, but possibly its magnitude is not. It has been estimated, for example, that if all the present energy requirements of the United States were to be supplied entirely from fission reactors, it would be necessary to dispose of radioactive fission products equal to those from the explosion of some 200,000 atomic bombs. The solution to the problems of waste disposal, already partly at hand, is largely a geological or a geochemical matter.

Power from nuclear *fusion* is quite another matter, which we will presently discuss. But were Mankind to attempt to rely on energy from nuclear *fission* alone, geologically speaking the time will only be tomorrow when solar energy also will have to be harnessed. Here it should be recalled that the solar energy reaching the earth annually is about 3200 times 10^{18} B.t.u. or about 32,000 times present-day world requirements, and some 320 times the projected needs a century from now. The fact is, the solar energy reaching a plot of land measuring as little as 6000 square miles could supply all our energy needs today. In other words, if 100 percent recovery were only possible, the solar energy potential of the Hawaiian Islands alone might be enough; that of Massachusetts could well be more than ample. Obviously, engineers are called for. Note that geology can scarcely play a major role in solving this energy riddle.

The engineering problems involved in making solar energy readily available at reasonable costs probably are of the same astronomic order of magnitude as those connected with the effective harnessing of the energy of nuclear *fusion* for conventional, or even unconventional, power purposes. Nevertheless, the future broad use of this energy of fusion seems inevitable. As you know, deuterium, a heavy isotope of hydrogen, will probably be the "fuel." The energy potential of the deuterium content of one gallon of sea water has been variously estimated by Hubbert, Post, and others as approximately that of 300-350 gallons of gasoline. It is evident then that the oceans contain enough deuterium—properly utilized—to take care of the world's energy requirements, however multiplied in the future, not merely for hundreds, but for billions of years. Some geochemists may be involved in the present and projected reasearches, but certainly not many "old style" geologists.

The cost of extracting deuterium from water is already relatively low, and enough is presently being produced in the United States in connection with our atomic energy program to supply our present total energy needs—that is, if it could now be used as a fuel. The problems involved in the controlled burning of this potential thermonuclear fuel are admittedly enormous; but that they will be solved—and, note again, not by "classical" geologists—can scarcely be doubted.

When they are, there will be few, if any, geological problems of the waste-disposal type, for the burning of deuterium and tritium produces inert gases.

There are those pessimists who secretly believe, or openly assert, that the much-discussed modern menaces of nuclear experimentation, in addition to actual nuclear warfare—not to mention biological and chemical warfare, the devastatingly destructive potentials of which we tend to minimize—are likely to keep Mankind from overpopulating this planet. But even the scientific optimist realizes that Mankind's fecundity problems are difficult enough if they are to be solved by enlightened rather than by barbaric methods. This is true because, with some possible exceptions, the population problems are increased both by "humanitarian" approaches and by agricultural, medical, and general scientific advances.

Mankind's energy needs and population problems are closely interrelated, because peoples will, presumably, fight for energy requirements as much as for *lebensraum*. Should the problems attending the development of the practical use of nuclear fusion and solar energy be satisfactorily solved, at least one ancient source of world dissension could be partially eradicated. This would be true because, within certain limits, "have-not" nations would have, area by area, about as much solar energy as their erstwhile richer neighbors; and, for most, the sources of deuterium would be, for all practical purposes, unlimited.

The length of time solar energy will be available certainly is also of no immediate concern. There is only the present worry over methods of harnessing it. The time available actually is pretty well known because stellar evolution reaches a final stage only when the original hydrogen resources of a star approach exhaustion. The mean age of stars now approaching their thermal death is considered to be approximately 3 billion years. Such stars are some four times as heavy as our sun and are calculated to have 1/16 its life span. In the course of time, stars of progressively smaller mass will get their death warrant—the sun itself by these estimates not reaching the end of its rope until about 47 billion A.D.

There should be plenty of time for experimentation!

Now let us consider whether there are any *physical* features of the earth which will throw some light, however obscure, on Mankind, his evolution, and his future, regardless of how he handles or mishandles his energy requirements and population problems, and regardless of the role geologists can, or will, play in the problems involved.

In some respects the earth is apparently a nearly if not quite unique speck in the universe. As you know, until relatively recently it was a common assumption that the stars, the sun, our earth, and interstellar material were similar in consisting in part of iron and silicon and other so-called "terrestrial elements;" but von Weizsacker and others now believe that such "terrestrial elements" as characterize our planet form as little as one per cent of all cosmic matter, the rest being a mixture of hydrogen and helium. Furthermore, Harlow Shapley has estimated that among the billions of stars in our galaxy only one system of planets appears likely to form in about 6000 million years.

To carry this latter point further, then, it would be unscientific to assert that there are no other planetary systems similar to our own, but neither is there certainty that they do exist, and there is reasonable doubt that, in any case, they can

be numerous. Moreover, among all the possible planets, the chances that one might be a suitable abode for life—in any form that our limited knowledge presently permits us to conceive of life—are quite small. This is true because many factors must be just right in order to sustain life, among them the ability to maintain *relatively* uniform temperatures throughout hundreds of millions of years, as our earth has done. This is a prime requisite because continuously propagating life, *as we know it*, is normally possible only between the freezing and boiling points of water. This is a geological fact of life which perhaps has received too little attention.

Maintaining the critical temperature range requires some doing! Our planet must be just the right size, just the right density, just the right distance from its parent sun, with just the correct periods of rotation and revolution and the correct orbital shape. Of course, it must also have readily available, at and immediately above its surface, just the right chemical elements. It is, it does, and it has!

Were not the permissible ranges in these physical, astromathematical and chemical functions maintained, the earth would obviously be too hot or too cold, or possess too dense or too rare an atmosphere, or have too limited a spectrum of chemical elements to support the stuff of life, protoplasm. The chemists and geochemists have been looking into these matters, which the historical geologists have tended to neglect.

It may well be that the earth is a fourth-rate planet moving about a third-rate sun which is part of a second-rate galaxy, but, with Candide, geologists may with caution still contend that it is "the best of all possible worlds."

In the latter connection it may be pertinent to register a personal observation, which may not be soundly based. One gains the impression that most scientists who are not actively engaged in the theoretical or practical aspects of the conquest of space, as well as a few of those who are, do not fully comprehend the problems of time, space, and change. For that matter, who does? Well, as much as any scientists, historical geologists do.

Without going into the problems of Minkowski space, and the so-called "clock paradox," it may be sobering to remember that there is an entire scientific subdiscipline known as extragalactic astronomy, and that our own galaxy, the Milky Way, is only one of many galactic and cosmic assemblages, although it probably comprises as many as 100 billion stars. Moreover, the speed of light, which is fast enough to encircle this planet seven times in a second, is sufficiently slow that it cannot traverse our galaxy in less than 100,000 years.

Our own solar system is pretty well out on one of the spiral arms of the galaxy, and has only made one full trip around its axis since the time of the great Pennsylvanian coal swamps, and only two circuits since the vastly remote end of Precambrian times.

The conquest of outer space may not be impossible, but it will involve difficulties sufficiently complex that scientists may return for awhile to the pressing terrestrial, or even planetary and solar, problems, which should admit of more immediate solutions. And incidentally, when the first men do reach the moon it would be advantageous if the party were made up largely of geologists—presently an unlikely eventuality.

The bases for, or the fundamental causes of, the apparent singularity of the

earth—within the majestic cosmos which the astronomers are beginning to know —make good subjects for religious, philosophical, and, yes, geological debates. They should be considered by geologists with just as much assurance as scientists in other disciplines have shown in their invasion of the geological domain.

Let us now assume merely that the earth does show some evidence of being a quite special cosmic speck; presently rather inexplicably so. Is man then also a rather special organic complex? Discussions of this question have long been marked by considerable heat. All Renaissance suggestions that man is an animal that is merely warp and woof of the highly variegated rug of life were, of course, regarded as high-order blasphemy. Today, very few educated people question man's kinship with all living things, but there does appear to be a growing recrudescence of the ancient science-vs.-religion trend.

Is there any scientific evidence for a "special" position of man among the animals? Well, let us review a little. Man walks erect, has stereoscopic vision, has opposable fingers and thumbs, a large cranial area, a vermiform appendix, and, sometimes, a tail with relic muscles to wag it. Of course, one or more of these features, as well as many others, he shares with some other mammals.

Man has other characteristics, too. He has an unusually large development of the frontal area of the brain, and the left frontal region, known as Broca's area—not seen for example in the apes—probably controls speech. He thus has the power of oral communication, which some psychologists believe is the one chief feature which sets him apart from the other animals; the ability to think creatively; a moral sense, however poorly developed; the capacity to adjust to temperature changes; and, in part, the ability to modify or change his environment. In addition, there are still other important special features sometimes furtively mentioned but not commonly enough catalogued. For example, the female of the species is almost unique in possessing permanent rather than temporary breasts, there is a sustained adult non-seasonal sexual drive, the gestation period is unusually long, sexual maturity is markedly retarded, and the human infant is exceptionally infantile and has an extraordinarily long period of dependence on the mother. Despite many ribald jests to the contrary, there also is now, and for a long time has been, considerable male constancy. Hence the cultural unit and device of the family came rather early into existence.

In short, this entire complex of characteristics man does not share fully with the other animals, not even with those most closely related to him.

With all his special features, however, man is still a primitive mammal in that he retains the five original digits which characterize the central mammalian stock, and a dental differentiation that shows no wide departure from the original tooth structure of some of the Eocene primates. Moreover, the reduction in teeth from the primitive mammalian number of 44 is slight indeed. Thus, man is certainly "special" in that he possesses an extraordinarily large and at least partially specialized brain, coupled with feet, hands, and teeth of antiquated, generalized type—the very structures which in most mammals display the greatest evolutionary specialization.

This is a particularly notable disharmonic design, and, at least so far as the

retention of generalized features is concerned, augurs well for a long-term future for mankind.

Now let us briefly consider how long man has lived in the Americas. Helmut de Terra believes his "Tepexpan Man" of the central Mexican basin lived 11-12,000 years ago, and Arnold and Libby's radiocarbon dating of reasonably closely associated peat at least partially confirms this estimate. The now famous Russell Cave deposits clearly show that man lived almost as early in the southeastern United States. Moreover, George Carter and others now believe that "early man" lived in the San Diego area at least 30,000—perhaps 80,000—years ago. One of the oldest radiocarbon dates for man in South America is 8639 years plus or minus 450. The analysis was made by Arnold and Libby on burned bones of sloth, horse, and guanaco, associated with human bones and artifacts found in Palliaike Cave, Chile.

Although it is not absolutely certain, probably all New World men are representatives of *Homo sapiens*. What *is* certain is the fact that in the Americas, as elsewhere, there has been a positively explosive radiation of man, concurrent with a burst-like population increase—some, but far from all, of which can be attributed to migration.

Again, the notable fact is the unparalleled—in the geological record—rapidity of man's increase in numbers and his movement into virtually all of the world's climatological zones, geographical positions, and ecological niches. This point may be underscored by considering his increase in the Americas since the first European migrations. At their inception, less than 5 centuries ago, there were, of course, a few mongoloids in North and South America, but some good estimates rate the entire population of the Americas at less than a million—and few go as high as five million. In any case the rate of population increase has certainly been more nearly geometric than arithmetic.

Thus, we are confronted once more with man's quality of being biologically atypical—or, if you wish, special.

Any study of the *physical* features of the earth demonstrates that they have been formed, and reformed, repetitively by processes which, if not wholly uniform throughout geologic time, are uniform enough to give some validity to the Hutton-Playfair doctrine of uniformitarianism.

On the other hand, any study of *organic* evolution shows that it is long, slow, non-repetitive and infinitely varied. As George Gamow once remarked, "It took less than an hour to make the atoms, a few hundred million years to make the stars and planets, but three billion years to make man."

What other lessons from geology and paleontology may have bearing on the present problems of Mankind? Let us merely cite a few.

Any organism tends to adapt itself biologically and physico-chemically. This is a demonstration of the unending quest for equilibrium which is just as strong in the living world as in the inorganic. But when perfect equilibrium has been reached, the organism is necessarily perfectly adapted to its environment. At such a point, the animal or plant ceases to change—or, if you wish, to evolve.

Arnold Toynbee has called such a static situation, as applied to Mankind, "the nemesis of creativity." And, if one is thinking about evolution, Dr. Inge's

aphorism, "Nothing fails like success," may be accepted as essentially correct. For example, the Precambrian "bristle worms," of more than half a billion years ago, were essentially the same as their modern descendants. The adaptation to their environment was, and is, nearly if not quite complete. In short, they reached near equilibrium in the ancient past. Among their group, however, were some poor unadjusted mavericks which were less successful at the time but possessed what has been called "creative instability." From some such primitive maladjusted organism, man himself may have at long last evolved. It certainly was not from any well-adapted ancient creature.

One may ask: do the Russians have creative instability? Are we well adapted, content?

Evolution, then, only proceeds through unstable organisms. Adaptation terminates whenever perfect equilibrium is reached, and thus, in the end, adaptation negates itself. The animal which, through geological epochs, becomes more and more efficient in meeting its routine, day-by-day problems of living and reproducing its kind will be superior to most or all of its competitors in its own field. Poor, indeed, will be its fortunes, however, should that special field be changed—and the more certain its extinction should its environment change suddenly.

The apparently abrupt extinction of the "ruling reptiles" of the Mesozoic is a striking case in point. The theory that the rise of the mammals caused the decline of the dinosaurs and related reptiles is oft repeated. Actually, the rise of mountain ranges and, indeed, of continental masses, the possible increase in volcanism, and alterations in the mutation rate possibly as a result of changes in climatic and radiation condition, as well as general racial senescence, were among the more compelling factors in the sensationally sharp reduction of the reptilian population. The replacing warm-blooded mammalian fauna was blessed with far greater capacity for survival under sudden and relatively severe changes of temperature. Interesting in this connection is the fact that the insects are far less susceptible to radiation damage from "fallout" than is man. The possible analogy is tempting. Will the insects replace the mammals as the mammals replaced the reptiles?

One of the possibly overworked parables from paleontology is the story that the "specialized" have sudden moments of prominence whereas the "generalized" may be relatively undistinguished but very long-lived.

There is, of course, considerable evidence for this contention. The brachiopod, *Lingula*, in its simplicity has persisted with little change for half a billion years, whereas *Prorichthofenia* and *Leptodus*—whose pedicle valves are so specialized that they look like corals or oysters—were limited to the Permian period. The persistence of such generalized forms as the scorpion and the cockroach throughout the hundreds of million years from middle and late Paleozoic times, respectively, is well known. Similarly, the decline and extinction of the highly specialized Mesozoic dinosaurs may be contrasted with the persistence of the generalized reptiles—the snakes and the turtles.

Such relatively sudden extinctions or evolutionary bursts, or at least periods of apparent acceleration of evolutionary change, probably have considerable bearing on our study even though they are imperfectly understood. We do know that

gene differences make possible gene combinations of galactic proportions, that not all mutations are lethal, and that, indeed, some mutants acquire adaptive advantages. To underline the difficulties here—and perhaps increase our philosophically based apprehensions concerning the future of Mankind—witness also the case history of the extinct echinoderms of the blastoid class. The genus *Pentremites* is a typical form which became most successful just before the abrupt extinction of the class in the ancient American seas. This blastoid paradox is further complicated because the very much younger Permian strata of the Island of Timor have yielded a profusion of other species of these echinoderms—67 species belonging to 20 genera—immediately prior to their complete disappearance.

There are, of course, various interpretations of such anomalies, but they cannot be elaborated here. We may merely mention in passing that the modern Ctenophore, *Bolina*, gives us an example of a reproductive phenomenon of sexual precociousness, or paedogenesis, which may have some paleontological significance.The larval stages of *Bolina hydratina* are sexually mature when they have reached as little as 2-5 percent their maximum adult dimension. This would be similar to a human offspring being sexually mature prior to birth. Through paedogenesis the possibilities for rapid population increases are, of course, spectacular. There are no precise analogies in the vertebrate stock, but it is well known that bulls are fertile when very far from fully grown. So are brook trout; so, indeed, are Andean Indian girls of 6-8 years living in the Alto-Plano of Peru and Bolivia..

Another geobiological phenemonon deserves mention. This is proterogenesis, or the abrupt evolutionary branching-out of a new type from an embryonic or early juvenile growth stage of another stock. This is well displayed in certain ancient corals—the Heterocorallia—which suddenly show a marked change in skeletal arrangement as compared with the rugose corals which aparently are immediately ancestral to them. Moreover, the new genera, *Hexaphyllia* and *Heterophyllia*, became relatively abundant essentially at the time of their introduction—Late Mississippian—and then, despite rapid migration to widely separated areas, they became extinct prior to the next epoch.

Other major groups may have originated in the same general fashion. In such cases, any hunt for the so-called "missing links" would be particularly frustrating, since, of course, they never existed. Perhaps man himself branched with proterogenetic abruptness from an early growth stage of some related primate stock. Should this sheer speculation turn out to be valid, the human "missing links," so-called, will not be found either.

We are living in a time of cataclysms: volcanism is rampant, earthquakes are commonplace, and radiation, both natural and artificial, is at a high level. Genetic changes may well be accelerating as probably they did near the end of the Mesozoic Era. Perhaps, then, there are proterogenetic possibilities in our own primate stock.

Let us now look briefly at another provoking matter—that is, the possible acceleration of events throughout time. Pierre Leconte du Nouy thinks that "Biological Time" differs from the ordinary time applicable to inert things, in that it flows at a different rate, being governed by a logarithmic rather than an

arithmetic law. This is the concept that enabled him to determine the real physiological age of a patient from a mathematical expression of the rate of healing of a wound.

Extending this idea, we may properly speculate that, as the planet grows older, the rate of repetition of the earth's major physical events is increasing—which it appears to be—and that, similarly, the tempo of generic production is quickening. Such possible manifestations of geo-bio-cosmic change would roughly square with Milnes' hypothesis of a kind of universal evolution marked by a "kinetic acceleration."

Whatever Mankind's complete history ultimately reveals, it appears certain that Man's near-mastery of the physical and organic worlds will, if he is not very careful, be his undoing. In short, he appears generalized enough physically to insure long-range flexibility and, thus, long-time survival. On the other hand, he has been a virtual megalomaniac so far as cranial specialization is concerned. Thus it is now reiterated almost *ad nauseam,* but accurately, that Man could, quite conceivably, cause his own extinction through the calculated malignant usage of the very flowering of his cerebral specialization, that is, the discoveries of modern science and medicine. But rarely if ever do we, as a nation, give proper consideration to the fact that Man can also achieve the same effect—paradoxically—by the well-intentioned, but unwise, use of the same new knowledge. For example, Man strives to build into each person the power to resist infectious diseases, and, being partially successful, he has further increased population pressures, energy requirements, and thus bellicose men and nations. And when he works directly to solve some of the other problems of over-population—which Nature, in the geological past, would have handled efficiently, if cruelly, and in stride—he is confused by a great diversity of suggestions, commonly emotional or political rather than scientific. In short, Man's specialization of "moral awareness"—something brand new in the geobiological world—handicaps him, and could even be lethal under certain extreme conditions.

Let us digress for one last time to explore briefly just one of the complications. Some of the old experiments of J. R. Slonaker possibly suggest that hunger for proteins and a deficit in amino acids may increase the fertility of animals. On the other hand, diets rich in protein may tend to reduce fecundity. Parenthetically, paleontologists probably have not paid enough attention to the possible effects of ancient dietary modifications on the life history of many groups of animals.

The Slonaker experiments were conducted with rats, but the results may be the same with men. Although there are other possible explanations—and Slonaker's work has been severely criticized in many if not most quarters—it is true that nations with the highest birth rate are those whose diets do not contain more than five percent of animal proteins, as in parts of Latin America and certain sections of the Far East. On the other hand, Sweden, with the lowest birth rate, has one of the highest rates of animal protein consumption. Neglecting for the moment the possible effects of religious tenets and birth-control practices, these facts and other related ones have led to the thesis that *overpopulation does not cause starvation but that starvation is the cause of overpopulation.* If this be fact rather than fiction, it challenges the contention that the humanitarian approach

can only result in increases in world population, and inadvertently in world problems. That is, since we insist on providing for the world's undernourished, at least some scientists would now suggest that the present population explosion actually could be arrested quite simply: that is, by serving all the ultrafecund starving peoples more and better protein-rich foods.

The foregoing problems, all too incompletely outlined, are as important as they are complex. Unfortunately, answers have not been supplied; perhaps few can be given at present. Therefore, it seems clear that now is an appropriate time for a number of us to stretch our thoughts. It is apparent that above and beyond specific and narrow investigations of inner or outer space, or even of the earth, its elements and its organisms, there is urgent need for rigorous study of some of Mankind's broad, general problems which cry out desperately for solution. Geologists, however—with a few exceptions—commonly appear embarrassed to engage in such researches. They should not, with their training and special knowledge—however lowly may be the order of that knowledge—leave the interpretation and direction of our future solely in the hands of economists, historians, philosophers, political scientists, militarists, legalists, and plain politicians. In the free world, at least, most of these experts are able men of good will, and in general they receive far too much criticism and too little credit; but, to err greatly on the side of understatement, in a scientific age one may with reason contend that the best of them possess talents and insights no more special, and no more applicable to the problems at hand, than do the scientists—among whom the geologists, because of their preoccupation with time, life, and change, are likely to be as philosophically inclined as any of their colleagues.

The phrase "Scientists should always be on *tap* and never on *top*" apparently originated with the late British economist, Lord Josiah Stamp. At any rate, it is oft repeated and in many circles still appears to be accepted as sort of eleventh commandment. Parenthetically, the very designation of some non-scientists as "humanists" probably subtly suggests to the public that scientists are inhumanists, possibly even inhuman. Actually scientists as a group are as deeply concerned, if less articulate, about Mankind as any other body of men. Therefore, although they should neither seek special favors nor strive to be on top—C. P. Snow perhaps to the contrary—it is essential that they really be on tap, and, further, that the tap be always open—open into a free-flowing pipeline to those who do hold the top management assignments in Mankind's economic, social, cultural, military, and political affairs. Progress has been made in this matter in recent years and months, though not much by geologists. If and when more progress is achieved, Dean Inge's wisecrack, "Nothing fails like success," may lose some of its wry pertinence. Presently, it is a rather painfully accurate dictum because scientific successes all too commonly are promptly turned into social failures, and certainly as much by non-scientists and society as by scientists themselves. Paraphrasing Einstein, we may say that for the present it apparently would be a simpler operation to annihilate man than to excise his evil spirits, or even some of his incompletely considered "humanitarian" impulses.

What about the future? The future of Mankind will not be very much brighter until the day dawns when we can say with some assurance that nothing

succeeds like scientific success. If and when such a day comes, I suggest that teachers of geology—who are more likely than most other scientists to have instilled in their students the importance of such broad general problems—will have had a substantial hand in its dawning. There is much more to geology than its economic aspects, interesting and important though they continue to be. The great teacher of geology instinctively knows that the philosophical aspects of the subject are the ones that have transcending values for him—and for his students.

N.A.G.T. ANNUAL MEETING 1961

The next annual meeting of the National Association of Geology Teachers will be held concurrently with that of the Geological Society of America, in Cincinnati, Ohio, November 2-4, 1961. The following notice is received from A. O. Woodford, national Vice-President.

"Papers for this meeting are solicited, without any implication that they will necessarily be accepted for oral presentation. Obtain a set of 4 abstract forms from the Secretary, Geological Society of America, 419 West 117th Street, New York 27, N. Y. Complete these and send them, with one extra copy, to Dr. A. O. Woodford, 760 West 9th Street, Claremont, California, *before June 15.*

Most N.A.G.T. talks will be limited to 10 minutes each."

NEIL MINER AWARD, 1961

Nominations for this year's Neil Miner Award are solicited. Members wishing to recognize an individual for "eminence in stimulating interest in the earth sciences" are invited to send his name and a supporting letter to the National President, Dr. C. D. Campbell, Washington State University, Pullman.

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GEOLOGICAL ENGINEERING CURRICULA

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ABSTRACT. Curricula in geological engineering that have been accredited by the Engineers' Council for Professional Development (ECPD) are analyzed in terms of the categories required by that agency. The engineering nature of geological courses is briefly considered as they relate to professional practice in industry. A wide range of curricular requirements has received ECPD approval. Common to almost all programs are a minimum core of calculus, physics, chemistry, and some thirty credit hours of geological courses.

INTRODUCTION

Geological engineering curricula in the United States that have been accredited by the Engineers' Council for Professional Development (ECPD) have been analyzed in terms of that agency's objectives and requirements. This has been done to ascertain the range of course requirements that has met with ECPD approval, and to compare accredited curricula in this field with those in other branches of engineering. The labor involved in making this compilation prompts the author to make available the results to others who may be interested without their needing to duplicate the tiresome process.

Certain questions and doubts lie in the background of the study. First, the question has been raised whether geological engineering is, in fact, engineering. Second, uncertainty exists as to how geological engineering differs—if indeed it does—from the professional practice of geology in industry. Third, comparisons of geological engineering curricula with those of other branches of engineering are difficult because much basic physical science is necessary for the former that is barely if at all pertinent to the others. Fourth, many individual geology courses are in part basic science and in part engineering, in that they treat practical applications to industrial needs. Fifth, recommendations and requirements for the Bachelor of Science degree in geology have come to resemble more and more the curricula in geological engineering. In fact, if some curricula were not labelled in their college catalogs, it would be hard to know to which degree they led. Sixth, just what is the best sort of education for students who are to enter the present and future mineral industry?

These and similar questions have frequently been discussed through the years. They are interestingly clarified by Neilson, Snelgrove, and Van Pelt (1960) in their article on the scope and function of geological engineering.

ACCREDITATION BY ECPD

The ECPD requirements are stated in its annual report, under headings entitled "Basis for Accrediting Engineering Curricula", approved in 1933, and

"Additional Criteria", approved in 1955. (All following quotations are from this publication.) The only pertinent part of the first section is the following article.

"VIII. Qualitative criteria shall include the following:

(1) The extent to which the curriculum develops the distinguishing characteristic of the engineer—ability to design, recognized in its broadest sense by the committee to be the ability to apply creatively scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design, and of the limitations of behavior imposed by such design; or to forecast their behavior under specific operating conditions; all as respects an intended function, economics of operation, and safety to life and property."

The section on "Additional Criteria" contains general specifications of subject matter and time distribution. It is quoted at length (but not in its entirety) because it may not otherwise be available to the reader.

"1 a. All curricula shall contain at least the equivalent of one academic year of mathematics and basic science about equally divided.

b. All curricula shall contain at least the equivalent of approximately one year, except as provided in 2-c, of engineering sciences including most and preferably all of the following:

(1) Mechanics of solids (statics, dynamics, strength of materials)
(2) Fluid mechanics
(3) Thermodynamics
(4) Transfer and rate mechanisms (heat, mass, momentum transfer)
(5) Electrical theory (fields, circuits, electronics)
(6) Nature and properties of materials (relating particle and aggregate structure to properties).

Only after careful consideration and determination that the fundamental concepts are substantially covered in other studies at an equivalent mathematical level, should one of these engineering sciences be omitted from a curriculum.

c. Because some engineering curricula are built in part on sciences not included in the preceding paragraphs, such curricula may contain for additional flexibility other basic or engineering sciences appropriate to their fields, to an extent equivalent to one-third of an academic year, in lieu of an equal portion of time otherwise devoted to the engineering sciences listed in 2-b.

d. Approximately the equivalent of one-half of an academic year shall be devoted to engineering analysis, design and engineering systems.

e. The curriculum shall be designed for an integrated sequential study in the scientific and engineering area. The mathematics and the basic science to be used proficiently in the work in engineering analysis, in the study of engineering systems, and in the preparation for creative design.

f. Depending upon definition of humanistic-social studies, the equivalent of one-half year to one full year of the curriculum shall represent the minimum content in the area of humanistic social studies. Of this content, at least one-half year should be selected from such fields as history, economics, government, literature, sociology, philosophy, psychology, or fine arts, and should not include such courses as accounting, industrial management, finance, personnel administration or ROTC."

DISTRIBUTION OF COURSES IN ECPD CATEGORIES

The ECPD accredited curricula in geological engineering have been analyzed and compared by tabulating their course requirements under the categories defined above. Assignment of some courses has been definitely stipulated, but for many others some interpretation of meanings has been necessary. The plan of distribution followed is explained below.

Under 1 a., "mathematics and basic science", have been included all mathematics, physics, and chemistry through quantitative analysis.

Under 1 b. (1)—(5), "engineering sciences", the named subjects have been listed. In section 1 b. (6), "nature and properties of materials (relating particle and aggregate structure to properties)", have been placed courses in crystallography, mineralogy, optical mineralogy, petrography, and petrology. These subjects treat primarily the nature, properties, and identification of the earth materials with which geological engineers deal.

Section 1 c., "other basic or engineering sciences appropriate to their fields", includes the introductory earth-science courses, that is, physical geology, historical geology, and paleontology. These give a general background of the physical, chemical, and biologic aspects of the earth. They are broad basic sciences of wide application in general education, agriculture, and other branches of engineering, rather than technical subjects in a narrow, specialized field. Physical chemistry is also placed here, it being both a basic and an engineering science because it includes thermodynamics, heat, and mass transfer. Graphics, surveying, and shop courses have also been placed in this category, though they are not specified, since no other place seems suitable.

The ECPD category 1 d., entitled "engineering analysis, design and engineering systems," must be applied to geological engineering curricula somewhat differently than to other branches of engineering, because of differences in nature of subject matter. This goes back to the definition of the engineer, in which "ability to design" is emphasized as his distinguishing characteristic. Design implies a product, which ECPD specifies as ". . . structures, machines, apparatus, or manufacturing processes, or works utilizing them. . ." The product of geological engineering in almost all cases is not material or tangible, as specified above, but instead consists of knowledge, understanding, judgments, and evaluations. Geological engineering, or applied geology, as contrasted with "pure" geological science, deals mainly with discovery and valuation of mineral deposits, and with assessment of underground conditions at sites of civil-engineering structures. Geological investigations for these purposes involve analysis, synthesis, and interpretation. These studies require a background substantially different from that for other engineering branches, and they result in conclusions on which may be based decisions to begin other engineering projects, not to begin them, or to modify their course or type. This is engineering where defined as ". . . to forecast their behavior under specific operating conditions; all as respects an intended function, economics of operation, and safety to life and property". As a consequence of these differences, design must be thought of as interpretation and evaluation. Geologic data are gathered by widely diverse physical and chemical measurements or observations, they are then analyzed for significance,

GEOLOGICAL ENGINEERING CURRICULA Accredited by Engineers' Council for Professional Development	Time required (years)	Alaska, Univ. of	Arizona Univ. of	California, Univ. of (Berkeley)	Colorado School of Mines	Idaho, Univ. of	Kansas, Univ. of	Louisiana Poly. Inst.	Michigan College Mining and Tech.	Mississippi, Univ. of	Montana School of Mines	Nevada, Univ. of Mackay School of Mines	Oklahoma, Univ. of	Pittsburgh, Univ. of	Princeton University	St. Louis University Inst. of Technology	South Dakota School of Mines	Texas, Agri. and Mech. College of	Texas Western College	Utah, Univ. of	Washington Univ. (St. Louis)
MATHEMATICS AND BASIC SCIENCES	1	18	17	12	20	18	18	18	20	18	16	16	18	16	13	17	18	17	17	18	18
Mathematics		12	12	10	18	14	8	12	10	8	17	14	8	8	10	8	9.3	11	14	14	13
Chemistry (Inc. Quant. Anal.)		10	10	12	10	10	10	8	10	10	10	12	10	11	10	8	10	12	12	10	10
Physics	1-2/3	7	6	10	9	7	9	9	6.7	3	6	6	10	7	10	8	4.7	4	9	8	10
ENGINEERING SCIENCES		4	5	3	2	3	3	3	2.7	2	4	3	3	3	3	6	2	6	3	2	4
Mechanics of solids		3	5	5	3	3	3	6	2.7	2	4	4	4	3	6	3	4.7	3	4	3	6
Fluid mechanics			3	4				7	2.7	2	3	3	1	6	2	3	6	4	9	4	12
Fluid dynamics																					
Electrical theory																					
Nature and Properties of materials		10	12	10	13	14	7		16.7		10	13	6	11	13		14				
OTHER BASIC OR ENGINEERING SCIENCES	Up to 1/3																				
Physical chemistry		8	8	7	8	3	9	8	2	4	6	6	10	7	14	6	4.7	3	10	5	8
Physical-historical geology					6	8	8		2	4	4	4	4	3	3	3	7.3	7		3	6
Paleontology					2				2.7		3	3	5	2	4	4	4	4		3	3
Surveying		2	3	3	5	6	6	4	4		4	4	1	6	6	6	6.3	4	4	4	6
Graphics		2	6	3	5	6	1	7							2	2	5.3	1	1	1	1
Shop. Engr. problems or measurements	1/2																				
ANALYSIS, DESIGN, ENGR. SYSTEMS		3	3	3	5	7	3	3	4	7	7	6	9	9	9	9	8	8	10	6	12
Economic geology		3	3		3	3	3	3	2	3	4	3	3	3	3	3	3.3	3	4	3	3
Structural geology									1.3	6	6	5	3	8	3	3	2.7	7		3	3
Sedimentation, stratigraphy									2.7					2							
Geochemistry									2								3.3	4	2	4	3
Geophysics				1	3	1	3	2		1	1	2	3		3	2	2	3	21	1	3
Field methods									3.3											18	
Geomorphology; Airphoto geology		2	3	1	3	2	2	2		2	11					3					
Mining, Mineral Dressing		11	9	3	5	3			3.3		6		6								
Metallurgy		2	3	1		12		5									0.7	2			
Petroleum engineering											8							9			
Seminar		1		14	16		16	6	6	6	2	6	6	13	6						
Electives in geology and engineering					8	4	5	5	6	8	6	6	9	4	14	3	2	6	2	6	6
Summer: field: Plane surveying		7	6		7						5	5		5							
Geological and mine surveying																					
	1/2-1	21	9	16	21	12	24	23	28.7	8	25	26	20	14	14	34	27.3	25	24	18	15
HUMANISTIC-SOCIAL STUDIES																					
		6	6	8	6	8		5	8	2	9	9	8	3	6	2	4	3	6	4	4
PHYSICAL EDUC., MILITARY, ORIENTATION																					
		6	1			8		12	7.3	14	2	9	6	6	24	2	4			7	
ELECTIVES (free)		6	1																		
		145	140	132	170	144	141	148	163-4	143	162	146	144	155	163	145	148	155	155	152	149
TOTALS																					
		49	61	36	60	52	49	39	47	62	62	44	43	65	52	42	47	58	58	64	51
MINERAL INDUSTRY SUBTOTALS																					

and are synthesized into conclusions of economic and engineering application. This product is understanding—or an approach to understanding, since all the needed data may not be procurable.

Under this category, then, are placed all geological courses not previously allocated as basic or engineering science, on the theory that they provide the information, techniques, and opportunity for practical solutions of economic problems. Some of them, or parts of some of them, are perhaps more basic than engineering, as commonly taught, but in these courses particularly lies geology's unique contribution to industry. Here engineering principles may be melded to geologic understanding. With these are grouped courses in mining, mineral dressing, metallurgy, and petroleum engineering, for which the engineering label is not questioned.

EXPLANATION OF THE TABLE

The tabulation includes all geological engineering curricula accredited in 1957 plus those added through 1959, with the exception of the University of Minnesota which has a five-year program. The date of accreditation is given with the name of the institution. Information was obtained from the most recent available catalog, which in a few cases was not the last one, so some requirements may have been modified. The column "Time required" is the amount specified in academic years by ECPD "Additional Criteria." All figures are in semester credit hours, though some institutions operate on the quarter system. Princeton University's catalog does not specify the credit hours for courses; the tabulation figures in this column indicate the number of class, lecture, and laboratory meetings per week, and should be comparable to the others. The degree granted at Texas Western College is Mining Engineering (Mining-Geology option), but it is included by ECPD with geological engineering curricula. Economic geology includes courses covering mineral deposits, petroleum and gas, ground water, mining geology, and engineering geology. The mineral industry subtotal includes all credits in geology, geological engineering, mining, mineral dressing, metallurgy, and petroleum engineering.

CONCLUSIONS

Perusal of the table brings out a number of interesting points. The outstanding impression received is perhaps the wide range of requirements that ECPD has regarded favorably. This may well reflect recognition of the breadth of the geological field. It is evident that certain institutions are preparing men primarily or almost solely for the oil business, while others serve mining interests. In contrast are curricula with less specialized training, whose graduates could turn equally well to any industry or to public surveys.

Total requirements range from 132 to 170 credit hours. The larger totals result mainly from either heavy summer field-course requirements or from the cramming of a five-year program into four years, or from both. Practically all institutions require at least one short summer field course, and several require two long ones, commonly one in surface or mine surveying and the other in geological work. The mineral-industry credits, including basic earth-science

courses and the specialized applications, ranges from 36 to 65. The larger figures here result mainly from the inclusion of much specialized technical work in mining, mineral dressing, metallurgy, or petroleum engineering in addition to the standard geological courses common to almost all curricula. The geological core of about 30 hours generally includes 6-7 hours in introductory physical and historical geology, 10-12 hours in mineralogy and petrography, and about 12 hours in structural geology, stratigraphy, and economic geology.

All the curricula require mathematics at least through calculus, chemistry through quantitative analysis, and a year of physics. Physical chemistry is present in about half the programs. Only three require neither physical chemistry nor thermodynamics, and seven include both. Mechanics of solids and of fluids are almost invariably prescribed, at greater or lesser length, but electrical theory is included by only half the institutions.

Concern for the student as a person and a citizen, rather than as a professional man, varies widely. The requirements in the humanistic-social studies group ranges from 8 to 34 credit hours. Weakness in this field can not in some instances be remedied by devoting unrestricted electives to these subjects.

Education in geological engineering has most certainly not been restrained by ECPD in a strait-jacket.

REFERENCE CITED

Neilson, J. M., Snelgrove, A. K., and Van Pelt, J. R., 1960, Curricular and professional aspects of geological engineering: Econ. Geology, vol. 55, pp. 1048-1059.

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SUMMER INSTITUTE IN EARTH SCIENCE AND MATHEMATICS FOR SECONDARY-SCHOOL STUDENTS OF HIGH ABILITY*

NORMAN H. DOLLOFF

ABSTRACT. A study of the physics and chemistry of water, as an introduction to a survey of earth science, proved to be an effective procedure for forty high-ability secondary-school students. This approach provided a basic resource of information and understanding on which students and teachers could draw in explaining diverse phenomena of the atmosphere, hydrosphere, and lithosphere.

A summer institute in earth science and mathematics for secondary-school students of high ability was held at San Jose State College in San Jose, California, from June 27 to July 22, 1960. The Institute, sponsored by the National Science Foundation, was designed to give these students an opportunity to enroll in courses that are not usually available in high school and that at the same time would not overlap courses that they might take in college. The general objectives were to enrich scientific and mathematical backgrounds, to acquaint the participants with professional opportunities, and to provide an atmosphere which would stimulate creative thinking. The human beings with whom we worked were among the most able teen-agers in an area of more than three-quarters of a million people; the subject-matter area was that of the planet earth. What more could one have asked?

Forty high-school students attended the Institute, of whom 22 were juniors as of last year, 14 were sophomores, and 4 were seniors. Except for a few highly recommended students, all had had the minimum equivalent of a laboratory science, three years of high-school mathematics, and letters of recommendation from teachers. All students commuted, including five from out of the state who lived temporarily in the area. The regular staff of the Institute was composed of faculty from the College. Visiting lecturers in the earth-science section of the Institute were highly qualified persons from the fields of chemistry, meteorology, science education, geophysics, astronomy, conservation, and weather modification.

During discussions of the project before it was presented to the National Science Foundation for sponsorship, it was agreed that the object of the course would be enrichment rather than acceleration. Earth science was offered in the science section because it is not ordinarily included as a course in high school, and materials were also offered in the mathematics section that are not ordinarily included in the formal succession of high-school and college courses. Further, it was thought that the earth-science offering should not be a variation on the usual

* Presented at the annual meeting of the N.A.G.T., Denver, November 2, 1960.

introductory college course in geology. To present such an offering would be, in a sense, acceleration, and the spirit of the Institute was experimental. Thus a situation existed in which traditional approaches could be disregarded, and, in fact, had to be disregarded. This presented a unique situation, for even in a one-man department it is often easier to follow some sort of conventional pattern than to go through the pain and time-consuming procedure of formulating and detailing a complete new course of study. So, with the tables cleared of established curricula, the problem was what to do and how to do it.

Two factors affected the final decisions as to procedure. One was the necessity of having some kind of unifying trunk idea, from which branches could spread, and the other was the need for some sort of philosophical approach, over and above subject-matter content, which would serve to characterize the project. The unifying idea came from a suggestion regarding the importance of water in present-day economies, particularly in California. Even a cursory consideration indicated that there are few natural phenomena on this planet that do not involve water, at least as a minor component, from aa to zebras and from migmatites to thunderstorms. Certainly an understanding of the role of water in geological phenomena would be a good starting point for further study. At least it offered a different approach from that of agglomerating a number of unrelated subjects, or building the Institute around some conventional topic such as minerals or weather and climate. But with only four weeks available, the content would have to be somewhat limited. Thus it was decided that the substance *water* would serve as the unifying concept.

The second matter was that of desired results. In what ways should the thinking, attitudes and insights of the students be developed? What should the strategy be? Generally, sciences have developed in three stages—not necessarily separate or even precisely definable. First come the facts—observation, taxonomy, compilation of data—the naming and collecting of things—the alchemist, the naturalist, the "rock-hound." Second come generalizations, hypotheses, and eventually laws—the bow was invented before Hooke, the canoe before Archimedes, and fire before Lavoisier—first induction, then deduction. (It is interesting to note that much science course work follows this progression. In geology courses, for instance, effort at first is usually spent on identifying species of minerals, rocks, fossils and geomorphic features. Later in each course, and in more advanced courses, emphasis is placed on the understanding of principles and laws.)

Having indicated the first two stages in the development of science, we come to the third and last. This is the stage where the more independent sciences are utilized in solving problems in the most dependent sciences.[1] Before this stage can be reached, at least three conditions must have been established: first, the independent science or sciences must have reached an advanced state of maturity, with a very deep and broad development of principles, laws, and techniques; second, the more dependent science must have gone beyond the taxonomic stage, and the further it is in the second stage, the better; third, there must exist individuals with adequate, even rigorous, backgrounds in *both* sciences, who are actively working on the solution of problems in the more dependent science. In geology, this means that principles and laws of physics and chemistry are used, along with the

language of mathematics, to develop understanding and reveal new truths, establish new principles and laws and even new taxonomies. Consider the impact of certain individuals, and the physical and chemical principles with which they are associated, on the understanding of geological phenomena—such men as Newton, Stokes, Mendeléeff, Gibbs, Laue, Pauling, Max Planck. Without the work done by such men as these, the science of geology would be very much different from what it is.

This is also the chronology of education. The youngster collects minerals, rocks and fossils; as a youth he begins to comprehend concepts, principles, and laws; having been trained in mathematical thinking, and armed with the tools of physics and chemistry, the maturing scientist applies these to geological problems. Each stage, of course, continues the development of the previous stages. In fact, development of the later stages sharpens understanding of the earlier. It was the thesis of this particular institute that advantage should be taken of the mathematical and scientific backgrounds of these highly able secondary-school students.

Consequently, the first week was spent on an intensive examination of the physics and chemistry of water, with the focus on recent concepts of the energy and spatial relationships of oxygen and hydrogen nuclei and their associated electrons in the dipolar water molecule; the relationship between molecular moments, quanta, and the absorption spectrum of water; the particular crystal structure of ice; the phase diagram of water and the Gibbs phase rule; electrovalency and covalency. These then led to an understanding of the physical properties of water, such as latent heats of vaporization and fusion, specific heat, surface tension, solubility, and viscosity. The laboratory work for the first week consisted of fourteen experiments, from which each student could do as many as he chose. Many of these experiments were open-ended, in that students were encouraged to improvise or investigate further the principles involved. The experiments included such topics as determination of the heats of fusion and evaporation, capillary rise, index of refraction and its relation to the dielectric constant as an indication of the dipolar nature of substances, settling of solids in fluids, osmosis, the determination of the number of atoms in a molecule of hydrogen, the solubility of CO_2 in water, electrical conductivity, and the determination of pH. In order to diffuse learning from these experiences, one session was spent on the presentation of laboratory reports by students.

The second week was devoted to water and the atmosphere, the third to the hydrosphere, and the last to water and the lithosphere. It was hoped that the foundation of physical and chemical principles built during the first week would pay off in the succeeding weeks in enabling the students to make rapid progress. Thus, the students had developed an understanding of the relation between the vibration frequencies of the water dipole and the absorption spectrum of water. This relation was then presented, during the lecture at Lick Observatory, as supporting evidence for the presence of water in the atmosphere of planets, as well as helping to explain the heat budget of the earth's atmosphere, the ameliorating effect of the oceans on climates, wet adiabatic lapse rates, chinooks, and many

[1] Hubbert, M. K., 1938, The place of geophysics in a department of geology: A.I.M.E. Tech. Pub. 945.

other phenomena that are due to the peculiar properties of water. The study of the phase diagram of water was used later as a basis for discussing the tendency of ice to melt under pressure, the fact that most clouds consist of liquid water even at temperatures many degrees below freezing, the wasting of ice by sublimation, and the deposition of minerals at higher temperatures than the critical temperature. Activities during these three weeks consisted in part of lectures by specialists on the extreme upper atmosphere, a demonstration with a seismic truck on methods of locating aquifers, weather modification including statistical evidence, an all-day field trip to mountains and seacoast, a field trip to a water-conservation district, laboratory exercises on growing crystals, topographic maps on the work of water, and selected slides and films.

There was hardly a limit to what these youngsters could absorb, provided a sequence was logically developed. Perhaps two instances of why such an experience was exciting and satisfying might suffice. One noon, after lunch, and with just a few minutes remaining before the beginning of the afternoon session, I was discussing the Coriolis Effect with several students and the remark was dropped that it would be interesting to try to figure out where the force would be at a maximum. One student took a paper napkin, set up a formula involving a trigonometric expression, differentiated it, set the result equal to a maximum value, and solved the problem. On the final examination, which lasted for one hour, the question was asked why, if the half-life of tritium can be considered as 12.5 years, any tritium still remains on earth. Two students managed to find time during the test to set up the equation (which had not been given in lecture) for the amount present now in terms of some original amount at time equal zero. One of the students came up with a figure of how much tritium must have been present for a modest amount still remaining, presuming the age of the earth to be 4.5×10^9 years. His conclusion was that the amount of tritium would have to have been many orders of magnitude greater than the mass of the known universe, and therefore that it must be forming at the present time, possibly by cosmic radiation.

It is difficult to evaluate an experience of this kind. An analysis of homework assignments and test results would obviously indicate a high response on the part of such a group of students, no matter what the content. Early in October, three months after the end of the Institute, it was decided to get responses of a subjective nature, and a letter was sent out to each participant offering three chances to respond. "1. What subjects or areas presented during the earth-science portion of the Institute do you feel were the most valuable? 2. What subjects or areas presented during the Institute do you think could have been reduced or improved upon? 3. General comments." The results are difficult to analyze statistically; they have to be done in kind—subjectively. The comments indicated greatest interest in the physics and chemistry of water, the week on the atmosphere, and the geology field trips. There was mixed feeling with regard to the laboratory portion of the Institute, depending upon the students' former experience; to some the first week was repetitious, to others it was a rewarding experience. The seismic demonstration was commented upon favorably. Some were still carrying on their crystal-growing at home. Apparently, some of the laboratory work on the hydrosphere and lithosphere could have been designed better. But the feeling

was unanimous that the over-all program was successful and the students appreciated the opportunity to get a glimpse of what a college environment was like. The staff not only felt that the Institute was a success but that the new approach produced worth-while results.

I had been warned by experts and in the literature that a group of high-ability youngsters can and do challenge even the most experienced teachers to their utmost effort. I most certainly agree. It was a new experience for me. These were not refugees from other disciplines. These were students who too rarely select geology as their first choice. It is my hope that of those forty perhaps a few—or even one— may now realize that there are unsolved problems in geology that can take all they can give, and that they will plan their future education accordingly. I quote from one student's reply to the questionnaire: "A direct result of the Institute is the nine books that I have since purchased to further my knowledge of earth sciences and related fields."

It is hoped that our application for a similar institute for 1961 will be approved. The staff recognized that the four-week period limited the amount of material that could be covered. We have recommended, therefore, that the time be lengthened to six weeks. This will allow greater use of library facilities, field trips, laboratory experiences, and unhurried discussions. The institute should be entirely in the physical science—earth science area, with a similar approach, the water molecule.

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TEACHING GEOLOGY BY TELEVISION: EFFECTIVE METHOD OR GIMMICK?*

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ABSTRACT. Increased use of televised geology courses has been accompanied by favorable and unfavorable statements about its effectiveness. Television instruction permits greater use of visual material and requires more thorough teacher preparation. College administrations benefit from the scheduling flexibility and reduction of staff teaching loads. The major disadvantages, loss of student-teacher contact and student resistance to televised classes, may be overcome by appropriate lecturing techniques and proper administration of the non-televised parts of the course. Televised lectures do not appear to have an adverse effect on learning.

Increasing enrollments in our colleges and universities have resulted in greater numbers of students taking first-year geology for science credit. Large lecture rooms and multiple sections have been used to accommodate the large classes. In recent years, television has been used on an increasing scale to solve problems both of space and of staff utilization. Some claim that television is a poor substitute for standard teaching methods, whereas others argue that it improves on these methods. As to geology, which group is right?

Teaching geology by television has both advantages and disadvantages. Television permits the instruction of smaller groups, thus eliminating the large classroom. Some subjects would not gain much by this, but I feel that geology does, because visual material that is often left out of a lecture in a large classroom may be used on television. Also the students in small viewing rooms do not become lost in a crowd but retain the advantages of a small group.

Expanded use of visual aids is a major advantage of television over the direct-lecture method, regardless of classroom size. In beginning geology, visualization of subject matter is of great assistance to the student. The television screen can be filled with specimens of minerals, rocks, or fossils, with parts of topographic or geologic maps, or with views of experiments that require close observation. Slides and film clips may be used with superimposed pointers and names. Gimmicks? Perhaps, but if teaching is improved, is the term gimmick properly applied?

With the almost infinite variety of methods of presenting material by television, the teacher himself becomes motivated to make use of them and so upgrade the over-all quality of his presentation. In addition, production of a television lecture requires a more thorough preparation of subject matter than for an ordinary lecture. This is necessary because the director must know the program structure and timing for proper production. It has been our experience at Purdue that the

* Presented at the annual meeting of the N.A.G.T., Denver, November 2, 1960.

teacher is challenged to do a better teaching job when he is faced with a television assignment.

Repeated lectures, often necessary with large classes, may be avoided, either by carrying simultaneous television to enough viewing rooms to accommodate the entire class or by taping a lecture and playing it back at hours that best suit the students' schedules and the school's space limitations. Both methods permit maximum flexibility in scheduling without adding a burden on the teaching staff. In large-enrollment courses, the use of video tape is a distinct advantage, as multiple lecture sections may be scheduled to accommodate the varied scheduling needs of the students.

The use of video tape thus permits scheduling flexibility and eliminates the use of a large block of rooms at one time, as is necessary when an entire class views the lectures simultaneously. It also leads to the use of the tapes in succeeding semesters—although this may or may not be advantageous. It is an advantage because staff members are relieved for other teaching assignments (except for administration of the taped course and laboratory instruction). A disadvantage is that, once a course is taped, there may be a tendency to consider it as prepared for all time, and to re-use it without redoing parts systematically to present a fresh approach. In arranging staff assignments, provision should be made to review taped lecture material periodically and to produce new lectures as a continuing project.

Perhaps the chief disadvantage of television instruction is the loss of teacher-student contact. Closely associated with this is student objection to televised teaching. Both problems may be dealt with simultaneously by the lecturer. He must maintain a relaxed yet precise composure. Our experience has shown that lecturing without visible notes and without a lectern or similar device helps in attaining this goal. Also helpful is an introductory lecture, in which the course is surveyed and all or most of the visual techniques are employed without any reference to them. This is designed as a "selling" program both for geology and for television instruction. The techniques are so incorporated that they naturally become a part of the lecture. In this way the uninitiated student is acquainted with the visual methods of instruction to be used throughout the course. During later lectures, the use of certain techniques will not distract him from the subject matter but will be quite natural. This approach to the course tends to break down the student's resistance because he becomes intrigued with what he can see in comparison with a conventional lecture room.

The barrier between student and teacher is also lowered by having the lecturer share in non-televised laboratory instruction and in field trips. In this way, he never becomes a performer but is truly their teacher.

Two methods of answering questions about lecture material have been used at Purdue to form a bond between teacher and student. In the first method, used in our large-enrollment classes, questions are handed to the viewing-room proctors and the lecturer discusses the questions personally with the students in their laboratory sessions. The other method has been to employ a talk-back microphone

in each viewing room, with direct answering of questions from the television studio during a question-and-answer session. Both methods have been successful when properly administered.

Lecturing techniques, personal laboratory instruction, and answering questions on lecture material have been effective in bringing the lecturer closer to the students. We find students audibly replying to questions designed to make them think even in classes where the talk-back system of answering questions is not used.

A disadvantage of televised instruction is the time consumed in preparation and production. A minimum estimate is twice the time spent for a normal lecture; often it is more than this if special effects are needed, or if lectures are recorded on video tape and later reviewed. The only justification for this is that if teaching is improved, the time is well spent. There are varying opinions as to what constitutes a full teaching load while producing a television course. There appears to be a full range between no compensation in load and the restriction of duties to the production of one course during a semester. College and university budgetary restrictions often preclude the recognition of extra time spent on televised course preparation and production.

Testing via television has not been used extensively. Its advantages are that everyone may receive the same view of a map or a specimen, that view being the specific one desired by the instructor, and that in single-section courses everyone can be tested simultaneously. It is most adaptable to tests which involve topographic maps, geologic maps and cross sections, and air photos. Fossils lend themselves to television testing better than minerals and rocks, because form is readily observable, whereas the various physical properties needed to identify minerals and rocks are not. A disadvantage of televised testing is that position in a viewing room, or inadequate vision, may affect test results. From evidence obtained at Purdue, these factors apparently do not affect efficiency in taking lecture notes. These notes, incidentally, are fully as voluminous when teaching is done via television as in the conventional method. Testing programs have been conducted on classes receiving televised courses and the results compared with those from control classes taught by conventional means. Learning effectiveness appears to be equal.

Student attitudes have shown significant positive response as the televised courses have progressed. The combination of more efficient use of space and staff, and the increased scope of subject-matter presentation, remove televised teaching from the gimmick category and place it among our most effective teaching methods.

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THE ENLARGER AS A COPY CAMERA

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ABSTRACT. The geology teacher is frequently faced with the necessity of making out with the equipment at hand. A photographic technique using a standard enlarger as a copy camera should prove to be a help to teachers needing fine copy work done at minimum expense and trouble. Only three items are necessary: an adapter back; a pair of copying lamps; and a home-made reflex viewer.

Necessity has led to the improvisation of many little-known tricks of the trade among geology teachers with limited budgets but unlimited ambition. Seeking vivid means of presentation, for both research and teaching, the worker soon finds that a personal knowledge of photography and photographic techniques is indispensable. In an effort to make out with the equipment on hand, and to devise more effective teaching aids, the writer found that the enlarger, a versatile darkroom accessory, can be equipped to function as an efficient copy camera. Three items are all that are needed for this conversion: a ground glass copy head or adapter back, which is inserted in the position of the negative holder; a pair of copying lamps; and a homemade reflex viewer for observing the image on the ground glass.

The ground glass copy head or adapter back, the most expensive of the three pieces of equipment, must be one designed for the particular enlarger being used (see Figure 1). These may be purchased on the market. The price is reasonable compared to that of other copying equipment. The writer uses a 4 x 5-in. Omega DII and a 4 x 5-in. Solar Enlarger. Copy lamps can be made easily and economically from a pair of gooseneck desk lamps. Or, of course, standard photoflood reflectors may be used.

The third item, the homemade reflex viewer, may be constructed of wood, cardboard, or other material. It rests directly on top of the copy head. A small mirror is mounted in the reflex viewer at an angle of 45°, as shown in Figure 1. This permits the 4 x 5-inch image on the ground glass to be reflected to a vertical position for comfortable viewing. If the mirror is mounted at any angle less than 45°, the reflected image will not be vertical, and composition will be difficult. The reflex viewer is painted flat black on the inside to reduce light reflection. The reflex viewer designed by the writer is shown in Figures 1 and 2.

Figure 3 shows a 4 x 5-in. Solar Enlarger used as a copy camera, and a reflex viewer designed for it. The inclinations and needs of the worker will naturally dictate the style of the viewer, materials used in its construction, etc. When

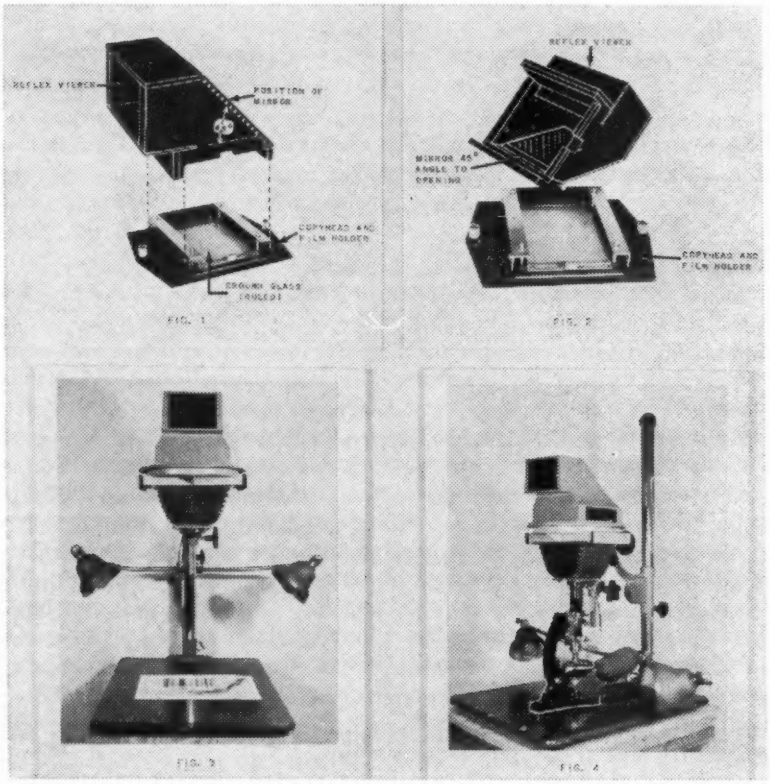

FIG. 1. Adapter back and reflex viewer, showing position of mirror and method of assembly.

FIG. 2. Adapter back and bottom view of reflex viewer, showing position of mirror.

FIG. 3. Solar Enlarger used as a copy camera, with reflex viewer in position for megascopic photography.

FIG. 4. Solar Enlarger used as a copy camera in photomicrographic work.

any enlarger is used as a copy camera, the lamp house and condenser lenses are removed, and the copy head and reflector back are placed in the enlarger.

The use of the reflex viewer for copying has several advantages. The apparatus is economical and easy to construct; large subjects, such as maps, may be composed and conveniently copied; and even though the plane of the film may be above the observer's head, the reflex viewer makes the work comfortable. Still another advantage of the reflex viewer is in photomicrographic work (see Figure 4), where the operator can compose the picture from a seated position, which is desirable when working for long periods of time.

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THE NEW MINERALOGY—PRINCIPLES AND EXPLANATIONS OF MINERAL PROPERTIES*

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ABSTRACT. An important aim of a course in mineralogy is to show, on the basis of crystal chemistry, why mineral properties exist as they do. The coordination principle of crystal chemistry explains crystal structure and chemical-element ratios; the substitution principle explains solid solution, and thus the many departures from ideal formulas found in minerals; the principle of bonding forces explains hardness and directions of cleavage. Other principles of significance are those of abundance and anion dominance.

Having learned the "why's" of mineral properties, most students can predict the physical properties of a mineral if told the composition and structure.

The principal aims of a mineralogy course are (1) to learn some of the unique properties of the crystalline state, and to learn to identify common crystal forms and systems; (2) to learn to identify minerals by their physical and chemical properties and by their associations; and (3) to understand, on the basis of crystal chemistry, why the mineral properties exist as they do.

It is the third point with which I am concerned here. The other two have been a part of mineralogy courses for many years. The first mineralogy course I took consisted mostly of memorizing crystal forms and identifying minerals. It is my impression that many mineralogy courses are built on this plan. I did not learn anything about explanations of mineral properties until I took graduate work.

Every year new information is added to the body of gelogical knowledge. It would seem that if we are to have any hope of including this new material somewhere in the educational process, it will have to be done through condensing older material and presenting it earlier in the student's experience.

There is an even more cogent reason for placing crystal chemistry in a beginning mineralogy course that comes in the sophomore year. That is to satisfy the desire inherent in the thinking student for the answer to his question, "Why?". In my view, crystal chemistry is the underlying solid framework which makes mineralogy a science and not just a collection of facts. There has recently been published a little paperback book titled *1001 Useless Facts*. I would favor placing in this category the fact that beryl has a poor basal cleavage. No student—even the thinking variety—is going to remember a little, isolated fact like that, because it has no particular meaning for him. But if he knows that the basic

* Presented at the 20th annual meeting, Central Section, N.A.G.T., Lawrence, Kansas, March 27, 1960.

structure of beryl is a stack of silicate rings made by the sharing of two oxygens in each of six silicon-oxygen tetrahedra, and that the small, highly charged beryllium and aluminum ions fit in between the rings and bond them tightly, then not only can he explain the poor cleavage of beryl, but also the great hardness and the crystal habit. Some quality of significance and meaning now lies behind the description.

When principle is seen to explain fact consistently, is not this the essence of science? A few principles thus serve to relate many facts. What are these principles in mineralogy?

1. *The coordination principle.* The sizes of ions in a structure govern the number of nearest neighbors and hence the shape of the coordinated units. I have found the construction of models by the students the most effective way to get this idea across. Balls of several sizes, made of wood, cork, or polystyrene foam, can be used. The polystyrene balls are so inexpensive that you can afford to give each student enough to construct several models. The balls can be colored with drawing ink to differentiate the various elements, and can be glued easily. All the new mineralogy texts I have seen have diagrams of the coordination polyhedra. These diagrams can be used as guides if necessary, but it takes only a little experimenting to show which regular arrangements are stable and which are not for two given sizes of balls.

The coordination principle probably has its greatest value in the study of silicates. The several ways in which silicon-oxygen tetrahedra polymerize result in separate SiO_4 units, chains, rings, sheets, and three-dimensional frameworks. These combine with cations of the right size to fit into the spaces left. Chain structures have smaller holes and the valence charge is such that aluminum, iron, magnesium, and calcium are the principal metals. The three-dimensional frameworks have larger holes and lesser charge available, so that the large, low-charged potassium, sodium, and calcium fit in. Calcium appears in both groups because its size is a minimum for the three-dimensional frameworks and a maximum for the chain structures. Thus it can enter both structures.

Each of these different structures requires a particular range of physical-chemical conditions for its formation, but this is perhaps better left to petrology if there is only one term available for mineralogy.

2. *The substitution principle.* The fact that ions of similar size and chemical nature may replace each other in the mineral structure explains the almost bewildering chemical composition of some silicates, as well as the type of compositional variation known as solid solution.

3. *The principle of chemical bonding forces.* The chemical nature of an element governs the strength with which, and the directions in which, it may combine with itself or with other elements. This explains the hardness and often the cleavage directions of minerals.

4. *The abundance principle.* Major rock-forming minerals consist of those elements present in greatest abundance in the earth's crust.

5. *The principle of anion dominance.* This is based on the large size of anions and explains the classification system almost universally used.

To test how well these principles have been learned, I have sometimes tried sketching or describing the composition and structure either of hypothetical minerals or of minerals not studied by the class, and have asked the class to predict the physical properties. Almost all students recognize the main properties, and a few give very complete physical descriptions of the minerals.

In summary, I believe that the presentation of these principles early in the course, and continued emphasis on them, provide a basis for an intellectually satisfying course in mineralogy.

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MINERAL RESOURCES FOR THE GENERAL COLLEGE STUDENT

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ABSTRACT. A course in mineral resources can be very popular with the general college student by providing a stimulating perspective on the essential role minerals have played and continue to play in the world. A consideration of the historical, political, and economic aspects of mineral resources is followed by a brief introduction to geologic principles and a study of the mineral fuels, metallic deposits, and selected nonmetallics. More geology departments should consider the advantages of offering such a course.

Many students majoring in history, economics, international relations and other fields are only remotely aware of the fundamental role mineral resources have played in shaping the modern world, and of the effect they continue to have on national economies and the relations between countries. Most students possess virtually no substantial knowledge of the role of coal and iron in the industrial revolution and of copper, aluminum, petroleum, and uranium in today's world; nor do they appreciate the role minerals have played in making possible the agricultural revolution. An understanding of the precious metals and many other mineral resources is similarly lacking.

Here is an important subject area of geology that can profitably be offered by geology departments to the great advantage of most students. Yet a perusal of the course offerings of departments in American and Canadian universities (A. G. I., 1960) suggests that only about a dozen institutions offer a course in mineral resources designed primarily for the non-geology major. Such a course has been given by the writer each fall during the past eight years, and has met with an appreciative response. The course carries three credits, has no prerequisites, and is open to all students. It regularly enrolls 35 to 40 students.

The organization of the course is patterned after Lovering (1943). Approximately two weeks are spent on historical and economic aspects of mineral resources and mining, from ancient times to the present. This is followed by two weeks of introductory geology principles. The remaining eleven weeks are concerned with the economic geology of the mineral fuels, the metallic deposits, and, very briefly, selected nonmetallics. Supplementary reading assignments round out the textbook material and bring it up to date. Numerous textbooks, symposia, periodicals, and other publications are available. The individual mineral products are not viewed simply as commodities, in the manner of the economist (although production and consumption and international movement of the various minerals are discussed). Rather, each mineral product is considered in terms of mineralogy,

geologic occurrence and origin, extraction and metallurgy, uses, substitutes, reserves, and prices.

A variety of activities supplements the classroom lectures. Ore minerals and other pertinent geological materials are displayed and made available for closer examination and study. Timely and instructive newspaper clippings and other printed matter are posted on the bulletin board. The leading newspapers carry national and world news on a great many topics relating to mineral resources.

About a half dozen problems and outside assignments are given. These include the calculation of mine reserves; computation of the value of mine shipments of mixed sulfide ores, using current published prices of the metals; drawing the coal fields on an outline map of the United States; preparation of graphs showing changes in price, tenor of ore, mine production, scrap, etc., for copper, aluminum, iron, or other metals, over a period of years. The last exercise also requires that the student analyze the curves and show how they reflect wars, depressions, government controls, and other factors.

A later assignment is the writing of a report on the mineral production of a state, each student being assigned a different state. The Area Reports volume of the *Minerals Yearbook*, as well as other references, are available.

After iron and steel have been discussed in class, a tour of a nearby integrated steel plant is made so that the students may actually see the numerous complex operations they have been reading and talking about. A tour of a petroleum refinery or a mine would similarly be of value.

Visual aids, such as films on mining and petroleum geology, have been shown sparingly because of the limited time available.

At the end of the term a student may, if he wishes, submit a scrapbook of mineral news, for which a bonus of 1 to 5 percentage points may be added to the term average. This voluntary project, in which more than half the students participate, sounds deceptively elementary, but it probably has a lasting value. It encourages the student to search the daily paper and other printed news media for news relating to minerals. He is made keenly aware of the role minerals play in almost every aspect of national and world affairs. Thus trained, it is hoped he will continue to be alert to this type of news for many years to come.

The course provides the student with a stimulating background and a new perspective into problems of history, economics, demography, and world affairs. He also develops some understanding and appreciation of the geologic framework in which man's activities have their setting. It is suggested that here is an area in which the geology department can make a noteworthy contribution to the academic fare of the college. For the small department, furthermore, it provides an additional course to general geology which may be taken by sizable numbers of non-geology majors.

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MAP REVIEW

Mount McKinley, Alaska: A Reconnaissance Topographic Map. Surveyed and edited by Bradford Washburn. Photogrammetry by Wild Heerbrugg, Ltd.; cartography by the Swiss Federal Institute of Topography. Scale 1:50,000; contour interval 100 feet. 1960.

This map, which measures 30 by 31 inches, includes the area between 150°34′ and 151°16′ West Longitude and 62°56′ and 63°15′ North Latitude. Features of water, ice, and snow, depicting conditions of glaciation as of 1951, are shown in blue; rock surfaces in brown; and vegetation in green. Relief is accentuated by plastic shading, and by use of the Swiss style of "rock drawing." (A detailed account of the "rock drawing" technique is given by Imhof [1951].)

Besides being the only large-scale map of the highest mountain in North America (and part of a national park), the map displays an outstanding assemblage of alpine glaciers radiating from the central massif and adjoining areas, with contoured surfaces, moraine patterns, ice falls and crevasses shown in excellent detail. The "rock drawing" adds a pictorial character to the map that makes it attractive as well as readable. Every tenth contour is shown extending through the rock areas, resulting in an especially fine example of a combination of relief techniques.

In an era when map-making is essentially the work of governmental agencies, the circumstances involved in the making of this map are unusual. Although a number of organizations, private and governmental, of both Switzerland and the United States, contributed generously, it was the dedicated effort of Dr. Washburn that brought the project to its successful conclusion. The story behind the map, which he has presented in the *Geographical Review* (April 1961), makes an interesting documentary of the immense amount of work involved.

This map, because of the spectacular area shown and the effective cartography, is highly recommended for use in geology classes at both elementary and advanced levels. It is available at $2.00 per copy, with special rates for multiple copies for educational use, from Dr. Bradford Washburn, Director, The Science Museum, Science Park, Boston 14, Massachusetts.

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A FIELD CLASSIFICATION OF APHANITIC IGNEOUS ROCKS FOR THE STUDENT

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ABSTRACT. A systematic scheme is offered for the classification of aphanitic igneous rocks, based chiefly on hand-lens identification of the phenocrysts. Secondary emphasis is placed on certain physical characteristics of the rocks, including color, luster, and the nature of cavities. The scheme is intended to provide a reasonable first approximation of rock identity in the field.

In most of the classifications of igneous rocks, emphasis is on the granular or phaneritic rocks. By some telepathic phenomenon, the student is supposed to relate the aphanitic porphyritic rocks to their implied phaneritic equivalents. The objective of this paper is to offer a scheme for the identification of aphanitic rocks based on those minerals, textures, and other features that are distinguishable with the hand lens. More detailed petrographic information may later require a change in the rock name, but the field name is a satisfactory first approximation.

This classification was devised by the writer while engaged in his second mapping project in volcanic rocks. It has been tested, and improved, by extensive field and optical studies. Several hundred students in petrology have been exposed to it. The general consensus is that classification of aphanitic rocks is "easy" with this scheme.

PHYSICAL CHARACTERISTICS TO BE CONSIDERED

The terms "light" and "dark" commonly cause confusion in petrographic definitions, wherein a dark reddish-brown rhyolite is a "light" rock and a light-green dunite is a "dark" rock. The present classification uses the terms "light" and "dark" in the sense understood by most students, and requires no special redefinition.

Luster of fresh surfaces is a valuable property in classification of aphanitic rocks. The more felsic rocks, rhyolite and trachyte, may be very dark in color, but they have a characteristic subvitreous luster, whereas the mafic rocks are commonly less vitreous. The felsic rocks are generally so fine-grained that they break with subconchoidal to conchoidal fracture, whereas the more mafic rocks often appear microgranular and break with a more uneven fracture. Although the felsic rocks may contain small miarolitic cavities, basalts and andesites are commonly vesicular and some basalts are honeycombed with minute cavities. Amygdules are more characteristic of basalts and andesites than of the felsic rocks. Spherulites and lithophysae characterize the latter.

The felsic rocks commonly contain lithic fragments, squashed microgranular lenses and blobs, and intricate "flow" structures typical of welded tuffs. (Much

obsidian is the result of welding, and many rhyolites are devitrified welded tuffs.) These features are also found in trachytes, latites, and andesites.

MINERAL IDENTIFICATION HINTS

Quartz—In some rhyolite, quartz is very dark in color, but its vitreous luster and lack of cleavage serve to identify it.

Potassic feldspars—When pink or flesh-colored, potassic feldspars are easy to identify. In some glasses and recent rhyolites, potassic feldspars are glassy and may have a yellowish tint. Cleavage may be very inconspicuous, but the rectangular outline helps to distinquish feldspar from quartz.

Sodic plagioclase—Striations are the only sure key to the light-colored plagioclases. Phenocrysts of hornblende and biotite are more common with sodic plagioclase than with the more calcic plagioclases.

Calcic plagioclase—When somewhat altered, as in many basalts, calcic plagioclase may take on a greenish gray color. When fresh, quite dark grays are common. Lath and "oatmeal" (thin plate) shapes are characteristic of calcic andesine and labradorite.

Biotite—Sometimes confused with hornblende in longitudinal section. With sharp point of knife, determine if there are small black flakes of biotite.

Hornblende—Commonly occurs in slender prisms or needles when developed phenocrysts are found in the rock.

Augite and other pyroxenes—Commonly occur in stout crystals which may be several times longer than wide.

Olivine—Commonly occurs in equidimensional grains, olive-brown to brown, rarely light green as in dunite.

Epidote—Commonly is responsible for the greenish color so characteristic of somewhat altered mafic rocks. Yet the mineral is rarely identifiable with the hand lens.

PROCEDURE FOR SYSTEMATIC CLASSIFICATION

First: Identify the phenocrysts in the rock and determine the relative proportions of the minerals that occur as phenocrysts.

Second: From these data, the usual mineral association is judged. Use the Bowen Reaction Series or Table 1.

Third: Consider color, luster, and the other properties where reference is made to them in the classification scheme.

TABLE 1.

Normal Association of Mafic Minerals and Feldspars

OLIVINE	—	CALCIC PLAGIOCLASE
PYROXENE	—	
HORNBLENDE	—	SODIC PLAGIOCLASE
BIOTITE	—	POTASSIC FELDSPAR
QUARTZ		

The common associations are in parallel horizontal lines, as biotite and potassic feldspar. The nearest neighbors, vertically and diagonally, are reasonable and common associates. Thus potassic feldspar is found with quartz, sodic plagioclase, biotite, and hornblende. Olivine is more commonly associated with pyroxene, and the feldspar is almost always calcic plagioclase. There are exceptions, to be sure, but the probabilities, based on statistical data, strongly favor the associations given.

Systematic Scheme for Classification of Aphanitic Rocks

I. Less than 5 percent phenocrysts and the rock is not a glass.
   - A. Light colored or dark vitreous—FELSITE
   - B. Dark colored or with amygdules or vesicles—BASALT

II. Phenocrysts comprise 5 percent or more of the rock and the rock is not a glass.
   - A. Quartz phenocrysts present.
     1. No feldspar phenocrysts recognized.
        - a. If rock is light colored, or has subvitreous luster even if dark gray, reddish brown, or purplish—RHYOLITE
        - b. If rock is dark colored, greenish gray to very dark gray, and micrograined like a basalt—QUARTZ BASALT (rare)
        - c. Mafic phenocrysts present
          - (1). Biotite—RHYOLITE
          - (2). Hornblende (assume sodic plagioclase)—DACITE
          - (3). Augite (assume calcic plagioclase)—QUARTZ BASALT
          - (4). Olivine (re-examine the rock, check quartz and consider the possibility of epidote for olivine)
            - (a). Olivine—QUARTZ OLIVINE BASALT (rare)
            - (b). Epidote[1]—DACITE
     2. Feldspar phenocrysts present
        - a. Potassic feldspars dominant—RHYOLITE (very common)
        - b. Potassic and sodic feldspars—RHYOLITE or QUARTZ LATITE
        - c. Sodic plagioclase only—DACITE
   - B. Potassic feldspar phenocrysts dominant (no quartz)
     1. No plagioclase phenocrysts—TRACHYTE
     2. Sodic plagioclase phenocrysts
        - a. Very small amount only—TRACHYTE
        - b. Plagioclase more or less equal to potassic feldspar—LATITE

[1] Epidote is common in somewhat altered basaltic rocks. It technically is not a "phenocryst," but when present in large enough crystals to be distinguished and identified, it is an aid in classification.

3. Mafic phenocrysts present
   a. Biotite—TRACHYTE
   b. Hornblende—LATITE
   c. Augite (re-examine feldspar determination)—LATITE
4. Feldspathoid phenocrysts present[2]—PHONOLITE

C. Plagioclase phenocrysts dominant (no quartz, little or no potassic feldspar)

1. Sodic plagioclase phenocrysts
   a. No mafic phenocrysts—ANDESITE
   b. Mafic phenocrysts present
      (1). Biotite (plus small amount of potassic feldspar)—LATITE
      (2). Biotite (no potassic feldspar) and/or Hornblende—ANDESITE
      (3). Hornblende—ANDESITE
      (4). Augite—ANDESITE
   c. Nepheline phenocrysts present—NEPHELINE ANDESITE
2. Calcic plagioclase phenocrysts
   a. Biotite and/or hornblende and/or augite—BASALT PORPHYRY
   b. Olivine and/or augite—OLIVINE BASALT
   c. Feldspathoid phenocrysts (leucite)—LEUCITE BASALT

D. Mafic phenocrysts only (no quartz or feldspar)

1. Biotite (assume potassic feldspar)—TRACHYTE
2. Hornblende (assume sodic plagioclase)—ANDESITE
3. Pyroxene
   a. Sub-vitreous luster or relatively light color—ANDESITE
   b. Dull or dark color—BASALT PORPHYRY
4. Olivine—OLIVINE BASALT

E. Feldspathoid phenocrysts only (rare)

1. Nepheline
   a. Light colors—NEPHELINE TRACHYTE
   b. Dark colors—NEPHELINE ANDESITE (rare)
2. Leucite
   a. Light colors—LEUCITE ANDESITE
   b. Dark colors—LEUCITE BASALT

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[2] Hand-specimen identification of feldspathoids is difficult. Nepheline, for example, is likely to be misidentified as a feldspar. But if a feldspathoid is identified, then the rock should be called by its technical name, such as phonolite.

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FIELD GEOLOGY FOR THE ADVANCED STUDENT*

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ABSTRACT. Three phases of field-geology training for the advanced student are suggested: (1) preparatory or office-library phase, (2) field phase or direct accumulation of geologic observations, (3) communication phase or interpretation and write-up of data for the use of others. Suggested approaches and examples of each of these phases are cited. Application of the principles should result in a better trained and more effective field geologist.

INTRODUCTION

First-hand study of the geologic features of the earth, rocks and their included deposits, structural relationships, surface forms and features, and geologic processes at work, broadly defines the term "field geology." But in reality geology starts in the office, moves to the field for further geologic data, and ends in the office with compilation, interpretation, and write-up. This departure from the general defiinition of field geology needs further consideration.

The following observations are old friends to the practicing geologist, but they may be strange to the advanced student beginning detailed field studies. It is hoped that these comments and suggestions, taken from teaching experience and from industrial and governmental work, will prove useful to others.

Many geologic field questions have already been answered by geologists of former years. Search of the literature, discovery of the pertinent geologic data, and their interpretation, may result in the required answer to the problem. More involved geologic questions may only be answered by diligent review and evaluation of the literature plus considerable field, laboratory, and office effort. This latter type of problem suggests a three-fold division of field geology: (1) preparatory or office-library phase, (2) field phase or direct accumulation of geologic observations, and (3) communication phase or interpretation and write-up of data for the use of others.

PREPARATORY PHASE

The Literature Review. How many times have we heard the complaints from students and professional geologists: "If I had only known of Allen's map, what a help it would have been," or "How much time I could have saved, if I had only had that report before I began my investigation." Insufficient office research time, or lack of knowledge where to search for needed data, may have been the basic causes for failing to find the available geologic information.

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* Presented at the 20th annual meeting, Central Section, N.A.G.T., Lawrence, Kansas, March 27, 1960.

Too often the lure of field work so tempts the geologist that he heads for the hills before he has adequately prepared himself to solve the field problem. Proper guidance at the student level may help eliminate this not uncommon practice. Obviously, the field geologist cannot afford to neglect the geological literature. To avoid its use, or to take only partial advantage of it, is to lose the services of a host of geological consultants who wait to be called from the library shelves.

For field work to be most effective, careful planning and effort should go into the preparatory phase. Has the problem been clearly outlined and are its limits well established? Will it be a full-scale scientific investigation, a reconnaissance study, a detailed or preliminary examination of a mine or prospect? The exact scope of the project should be understood by the student geologist.

"What is wanted?" leads logically to "What is already known?" Often the instructor tacitly assumes that the student is well acquainted with the geologic literature and knows how to find needed information. Is the young geologist acquainted with the *Directory of Geological Material in North America*, the *Bibliography of North American Geology*, and the bibliography of the geology in the state in which he is working? Has he heard of the exceptionally complete and well-indexed microcard library of Rocky Mountain geology? Does he know of the index to geologic mapping in his state, or the list of theses of thé country's major universities? Does he know where to find out whether geologic work is in progress or has recently been completed in the area he is to work? These and related questions should have affirmative answers if the student geologist is to do an effective field job.

Knowing what geologic literature is available and where to obtain it solves only part of the problem of field preparation. Critical reading and evaluation of the literature are also necessary. Here again guidance is needed. What should the student look for, how best can he evaluate the information?

The purpose and scope of the field problem determine what the student geologist needs to know. Proper evaluation comes only through critical reading and later field checks of recorded observations. A useful tool at this stage is the literature abstract card. Here can be recorded those data which are most pertinent. If abstract cards are properly set up for various types of investigation, obvious deficiencies in field data will appear in some reports as the abstract is prepared. Finally, the student should give his written evaluation of the report. Figure 1 is a sample of a useful abstract card for the general geologic literature.

The Airphoto-Map Review. Preliminary geologic data, derived from aerial photographs and topographic maps, are available to the field geologist before he ever leaves the office. Coverage is now obtainable for all parts of the United States. The student should know where to secure photographs and maps and the inherent delays in obtaining them. Too few students are aware that current copies of "Status of Aerial Photography," "Status of Aerial Mosaics" and "Status of Topographic Mapping" in the United States are free on request from the Map Information Office of the U.S. Geological Survey.

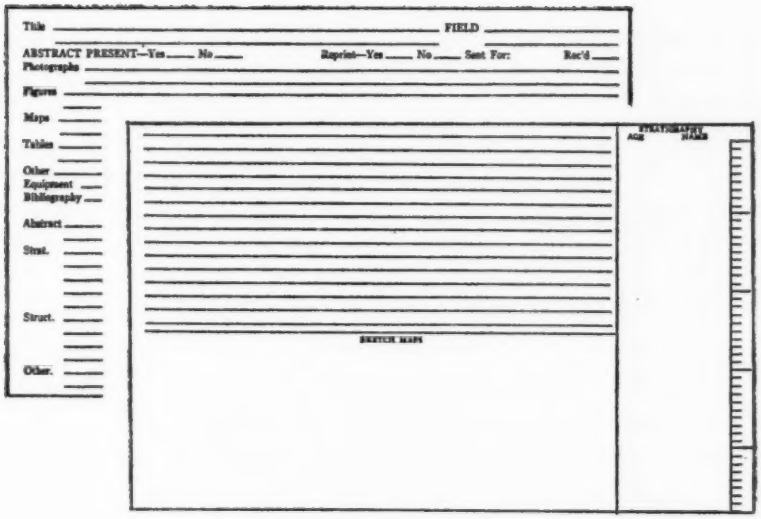

FIG. 1. Literature abstract card, front and back.

The aerial photographs should be carefully studied. A preliminary geologic map can be constructed on acetate overlays, and areas of good outcrop, areas of anomalous structure, visible lineaments, and similar phenomena noted for field check. From these data and those gained from the geologic literature, generalized stratigraphic columns and geologic cross sections can be made. Figure 2 is a simple line drawing from a vertical aerial photograph showing pertinent geologic details which require checking in the field. Such preparatory work will do much to make the field time more effective.

Similar studies can be made on topographic maps. Areas of anomalous topographic features can be outlined and field checks planned.

FIELD PHASE

The purpose and scope of the field problem, and the data available from the geologic literature, will determine the necessary field work. The assumption is made that the student knows how to use the various instruments of geologic field work, i.e. plane table and alidade, transit, compass, altimeter, and others.

Two major considerations of the field work are (1) the geologic locale of the area and (2) the length of time available for field work. The ideal locality is one which permits the student to do geologic field studies on sedimentary, metamorphic, and igneous rocks. A good stratigraphic section, with faults and folds for geologists interested in petroleum geology, or with mineral deposits for those interested in mining geology, is desirable.

Although the stages in the field work will vary according to the geologic locality and the purpose and scope of the problem, the first step is generally a

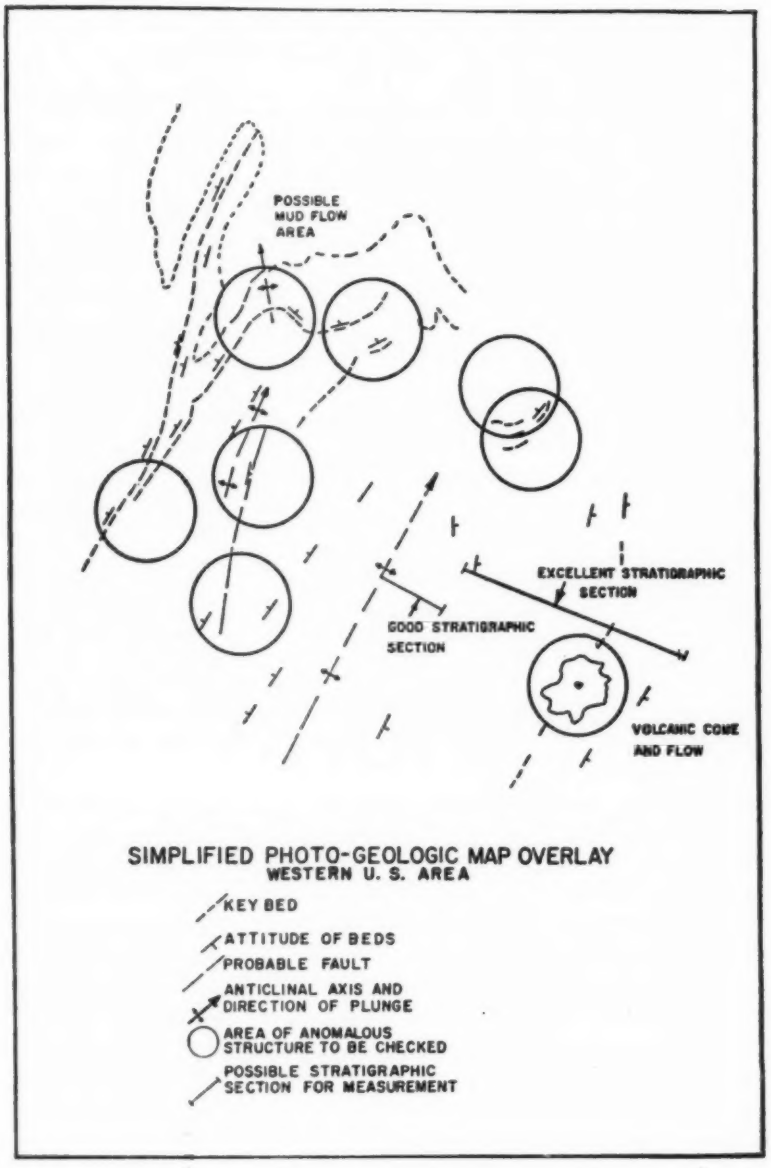

FIG. 2. Simplified photo-interpretation geologic map.

tour of the area to be studied. The student should have in hand the preliminary geologic map and the other information prepared in the office. These data will do much to orient him and to whet his appetite for the field work ahead. The second step should be a general field review of the stratigraphic units and the structural framework, to bring into focus the data gathered from preparatory reading. With these steps completed, the mappable units can be established and field work started.

Figure 3 illustrates a useful field sheet for recording stratigraphic information. Proper use will aid careful observation and will result in notation of pertinent data in a logical and readily usable manner. For all field problems, the student should be taught to record neatly and logically the observed data on the map and/or

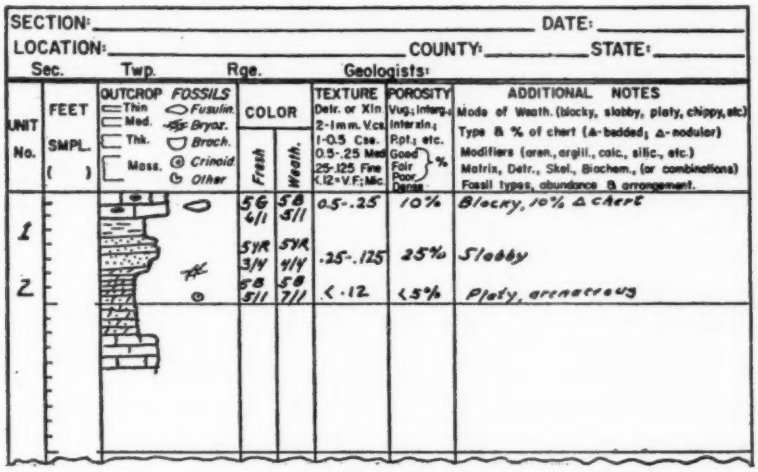

FIG. 3. A useful form for recording stratigraphic data in the field. After H. J. Bissell.

in the field notebook. How much the student records on the map or in his notebook will depend on the scope and scale of the project.

The almost infinite amount of detail available at each outcrop requires selection of data by the student. Common geologic features which the field geologist should be taught to recognize and record include attitude of beds, type of rock, foliation, lineation, joint sets, faults, alteration, primary structures and their direction. Perhaps the end product will not require or permit all these data, but it is better to have too much information than not enough.

The student should be familiar with the use of specially prepared forms for igneous-rock data, for grade-size determination of sediments in the field, for color description of rocks, and for other special purposes. Learning to use these tools early in his professional career will do much to make his field work more complete and effective.

Facts and inferences should be carefully distinguished on the map and in the field book. Data should be so presented that another geologist could use the information in checking or completing the project with the minimum of field review. In all cases where formation or rock boundaries are plotted, alteration haloes shown, or fault positions placed on the map, the validity of the contact lines should be carefully presented. Solid, dashed, and dotted contact lines do much to separate fact from fancy; errors which may then arise on geologic section or map are the result of interpretation and not of faulty observation.

Major discoveries of mineral deposits through additional field observation and re-interpretation of well-known geologic facts are indicated by three recent examples from the western United States.

A geologic map published in 1908 at a scale of 1/6000 was carefully reviewed in the field. The geologists who had prepared the map, now deceased but of considerable renown, had been careful to distinguish fact from fancy. Shaft locations and other cultural features were carefully plotted, outcrops were exactly located, alteration areas nicely demonstrated. Few factual changes were made on this map as the new field investigation progressed. Yet re-interpretation of the field facts brought to light a multi-million dollar ore deposit. This was no reflection on the work of the original geologists; their mapping had been done well. Geologic data from elsewhere in the area made a re-interpretation of the same facts necessary. This in turn led to the discovery of the ore body.

The careful studies of wall-rock alteration over blind ore bodies in the Tintic district, Utah, by Lovering and his associates, resulted in the discovery of a new and important lead-zinc ore zone. This is now under development by a well-known mining company. Critical review of the geology of the Four Corners area of the United States, and the resultant major oil discoveries there, is another example of success based on more complete observation and re-interpretation of geologic data.

The student may well ask himself, how many times have the same areas been mapped and remapped? Fifteen to twenty examinations are not uncommon for some mining and petroliferous areas. The success of present-day exploration teams in formerly well-studied areas is the result of more critical geologic observation and better evaluation of data. The comment of a field exploration supervisor to his group seems *a propos* for the advanced student geologist. "If you cannot read more critically, see the geology more clearly, better record what you see, and give a fresh interpretation to these data, you will be no further ahead than the geologists of 50 years ago." The remarkable success of his group of exploration men indicates that adherence to these principles has paid off in a practical sense.

The final map should be intelligible to any other geologist. It should be essentially completed in the field, not laboriously compiled in the office at some later date. Structural features, geologic cross sections, alteration phenomena and stratigraphic relationships recorded in sketches may prove invaluable in later review and write-up of the field study (see Figure 4).

The camera often records geologic data that the eye fails to see. The student's final report should include appropriate photographs to illustrate important observations.

The discovery of the unlabelled or improperly labelled specimen after leaving the field is a common occurrence. Labelling specimens as soon as collected, properly recording them with a simple number system in the specimen notebook, and pack-

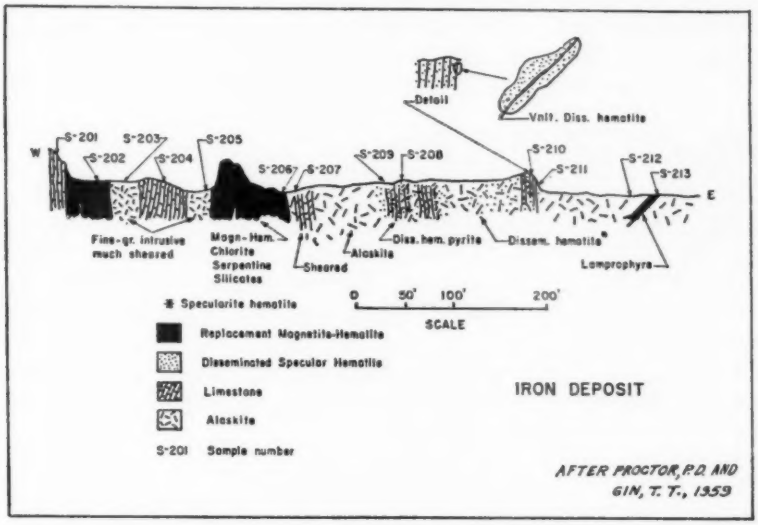

FIG. 4. Cross-section from field sketch, showing sample locations and geologic detail.

ing or filing them on return from the field, will set behavior patterns of real worth for future geologic work.

A field review of the map by the instructor, accompanied by the student, will permit evaluation of the work. Areas selected for checking should be far enough "off the road" so that the student realizes that proper field procedures, keen observation, and dimensional thinking in space and time are just as important off the beaten path as on it.

COMMUNICATION PHASE

Geologic data compiled in a field notebook or partly shown on a map must be presented in a logical and clearly written report—the end product of the student geologist's training. Since this report may be his first major attempt in organizing and presenting original geological work, he will need suggestions and direction.

Many students claim that the most difficult part of a field project is the understandable presentation of the field data to others. Certain steps seem warranted in order to make the final phase not only a pleasant and challenging task but also an effective one. Organization of data, outline of the report, choice of most pertinent

sketches and photographs, and concise and clear write-up of the information in report form make a logical approach to the problem. A simple indexing of field notes and other data acts as a good review of the field and library phases. Literature, map data, field notes, hand specimens form the backbone of the planned report.

A report outline is the next logical step. Many instructors require such an outline before the student begins writing the report. Others, unfortunately, give the go-ahead signal with no outline requirements. In the latter case the result is usually a befuddled student with a not very coherent report. The strict requirement of a detailed outline, together with a list of illustrations, will prove useful to instructor and student alike. The student will know his goals and the paths leading to them.

Effective write-up of the field data is a matter of practice; writing and rewriting until the student has completed a worth-while report. Guidance in use of his assembled facts, adherence to his approved outline, use of lead paragraphs, and expansion of these into coherent sections of the report will make the communication phase a challenging and enjoyable one. Help and suggestions, criticisms and compliments will be needed. An early review and recommendations on the first two or three pages of the written report will prove invaluable to the advanced student in guiding his writing.

The end product may not be perfect, but it should demonstrate coherence, conciseness, and clarity. These alone would be commendable contributions by cooperating senior and junior colleagues.

ACKNOWLEDGMENT

Thanks are due Professor R. E. Morgan for his helpful comments.

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MEMBERSHIP STATISTICS, NATIONAL ASSOCIATION OF GEOLOGY TEACHERS

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This year the membership committee, under the chairmanship of Robert E. Boyer, has embarked on the most vigorous membership campaign in the history of the Association. This report is presented with the object of helping the campaign along by encouraging healthy competition between the Sections. Also, since we have no historian, many of these statistics of our early years might be lost if not collected in one place.

The Sections of the Association were established in the order shown in Table 1.

TABLE 1

Section	*Year Organized*
Central	1938
Eastern	1950
New England	1952
East-Central	1953
Far Western	1954
Southeastern	1955
Pacific Northwest	1957
Southwest	1959
Texas	1959

Statistics for 1951, when the Association first became a national organization, are shown in Table 2. The institution with the largest membership was City College of New York, with seven; then Lehigh with five, and Hunter, Cornell, Franklin and Marshall, and West Virginia University, with four each.

TABLE 2

State	*Members*	*Institutions*
New York	34	16
Pennsylvania	20	10
Illinois	17	12
Indiana	12	No data
Ohio	11	No data

In Table 3, Section membership at the time each Section was organized is compared with present membership.

TABLE 3

Section	*Members in 1951 or at First Section Meeting*		*Present Membership*	*Increase or Decrease*
Central	32*	1951	56	+75 percent
Eastern	59	1951	169	+186 percent
New England	27	1952	42	+55 percent
East-Central	45	1953	99	+120 percent
Far Western	69	1955	66	—5 percent
Southeastern	31	1955	25	—24 percent
Pacific Northwest	13	1957	30	+207 percent
Southwest	30	1960	30	--
Texas	66	1960	66	--

* Exclusive of members who later transferred to the East-Central Section.

Except for 1958, figures are available for the number of members per Section for each year since 1955. These figures are given in Table 4.

TABLE 4

	Membership					
Section	*1955*	*1956*	*1957*	*1958*	*1959*	*1960*
New England	43	51	59	No data	55	42
Eastern	90	97	132	"	144	169
East-Central	64	67	74	"	74	99
Central	63	61	71	"	64	56
Southeastern	31*	34	39	"	22	25
Far Western	69	76	81	"	59	66
Pacific Northwest			13*	"	19	30
Southwest						30*
Texas						66*
No Sectional Affiliation	14	31	36	"	38	34
Total Membership	374	417	505	468	475	617

* Year of first membership listing.

Total membership of the Association by years, 1951 to 1960, is shown in Table 5. Membership has increased 303 percent since organization on a national basis in 1951.

TABLE 5

Year		*Members*
November	1951	153
November	1952	191
	1953	No data
	1954	No data
March	1955	374
May	1956	417
April	1957	505
November	1958	468
January	1959	475
October	1960	617

The five leading states in membership as of 1960, together with the number of institutions represented, are listed in Table 6.

TABLE 6

State	*Members*	*Institutions*
New York	82	37
California	66	41
Texas	66	24
Ohio	49	16
Pennsylvania	48	22

In Table 7 are listed the seven institutions with the largest number of members.

TABLE 7

Institution	*Members*
College of the City of New York (all divisions)	22
University of Texas	22
Ohio State University	14
University of California (all divisions)	10
Indiana University	8
Lehigh University	8
University of Michigan	8

In Table 8 the Sections are ranked according to the number of institutions represented in each. Average membership per institution is also shown for each Section.

TABLE 8

Section	*Institutions with N.A.G.T. Members*	*Average Number of Members per Institution*
Eastern	76	2.07
Far Western	41	1.61
Central	32	1.75
East-Central	32	3.06
New England	25	1.56
Texas	24	2.67
Southwest	16	1.88
Pacific Northwest	15	2.00
Southeastern	15	1.67

Among the conclusions that can be drawn from the data presented, the following point may be stressed. According to Table 5, the Association has shown a very healthy growth—over 300 percent in ten years. But Table 4 shows that four Sections have actually decreased in membership during the past five years. It is only because of increased membership in two Sections, plus the establishment of three new ones, that the Association's total has moved ahead.

TRANSACTIONS OF THE
NATIONAL ASSOCIATION OF GEOLOGY TEACHERS

REPORT OF THE PRESIDENT

It is a pleasure to report that in 1960 the N.A.G.T. began to reap some of the rewards which naturally stem from the hard work and dedication of the founders and previous officers of the Association. In short, the Association enjoyed a good year.

Membership at the time of the annual meeting stood at 631, compared with 519 in 1959 and 468 in 1958. The growth of the N.A.G.T. is healthy and, in fact, accelerating. The membership list, brought up to date by Secretary Freeman Foote, shows that although 34 members are presently without sectional affiliation, most of our membership is reasonably well apportioned among the nine sections. The Eastern Section, however, is becoming disproportionately large and may have to be subdivided. Particularly encouraging is the fact that the newly organized Texas Section has already enrolled 67 members.

If the N.A.G.T. continues to grow at the rate it enjoyed in 1960, the Association will be faced with many new, but perhaps not unwelcome, problems. For example, it is probably an error on the conservative side to consider that at least 10 percent of the some 28,000 American earth scientists may ultimately have sufficient interests in the teaching of geology and related subjects to be potential members of our organization. Presently we have enrolled only about one-fifth of that reasonable potential. There is much room for further growth.

During 1960 the N.A.G.T. achieved formal status as an Associated Society of the Geological Society of America. This new recognition brings with it added responsibilities as well as opportunities. Undoubtedly it will also further increase the Association's growth in membership.

Because of our new affiliation, the Annual Meeting of the N.A.G.T. was held in Denver in conjunction with the G.S.A. convention, at the Hilton Hotel on Wednesday, November 2, 1960. The excellent program, which was arranged by Vice President C. D. Campbell, consisted of nine papers given in the morning session under the co-chairmanship of D. M. Henderson and K. E. Grimm, and three papers delivered during the afternoon program. The latter session, under the chairmanship of Earl Ingerson, was devoted to the significance of foreign languages and literature in the study of geology.

The Annual Business Meeting was conducted after the well-attended luncheon, at which the Neil Miner Award was presented to Dr. A. C. Trowbridge—the presentation being made by Past President Robert Shrock. The newly elected officers were announced, and incoming President C. D. Campbell and Vice President A. O. Woodford were introduced and spoke briefly after having been enthusiastically received. The presidential address, entitled "Geological Perspective," was delivered immediately after the Business Session. The general arrangement of the over-all program as followed in 1960 has much to commend it. In future years, however, larger rooms will be required, and better advance publicity regarding the entire program must be developed. In addition, the meeting of the Executive Committee was, in 1960 as in former years, all too brief to consider properly the growing business of the Association.

The regional Sections of the N.A.G.T. also were active during 1960. The meetings of the Sections have always been unusually successful, and the vitality and general enthusiasm of our Sections must be maintained at all costs. We should not, however, lose sight of the fact that these effective units of our organization must be welded into a powerful and unified national Association. Moreover the interests of the teachers of geology at the richly contributing smaller colleges must be as vigorously represented as are those of the major universities. One of many factors in this matter involves the proper consideration of teachers on the staffs of the liberal-arts colleges who may well merit the Miner Award.

During 1960 your President and Robert Berg served the Association as representatives on the Board of Directors of the American

Geological Institute. Our relations with the A.G.I. are close and proving to be increasingly fruitful. They should be continued, as in the joint efforts of the two groups in connection with the Foreign Seminar in Geology, and with reference to the new Curriculum and Course Content Committee.

Your President's work during his term of office has been made simple and pleasurable through the fine cooperation of all the officers —among whom the presidents and secretaries of the regional Sections deserve special commendation. Treasurer Sheldon Judson's term of office has been marked by notable success, and he turns over his books to his successor, Wakefield Dort, with cash assets some $600.00 in excess of those available a year ago. Both Treasurer Judson and Secretary Foote are of the opinion that serious consideration should be given to the ultimate consolidation of the two offices with a reasonable subvention available for the Secretary-Treasurer's office. The Editor of the Journal, Robert L. Bates, continues in office, and during next year he, the President, and the Executive Committee will be giving consideration to the wisdom—and the expense—of making the Journal a quarterly, as well as to the problem of establishing an Association Headquarters.

In the solution of these and many other problems inevitably connected with a vigorously growing Association, I wish for President Campbell and all the other new officers of the N.A.G.T. notable success, as well as experiences as richly rewarding in new contacts and friendships as mine have been.

Respectfully submitted,
CAREY CRONEIS, *President*

CITATION OF ARTHUR CARLETON TROWBRIDGE FOR THE NEIL MINER AWARD
1960

The Neil Miner Award of the National Association of Geology Teachers was created to recognize "eminence in stimulating interest in the earth sciences." The recipient of this award for 1960 is Arthur Carleton Trowbridge, distinguished professor, administrator, research scientist and public servant. At age 75 he is still continuing an active career as a teacher and geological consultant and is a conspicuous example of the kind of earth scientist the Neil Miner Award was created to recognize.

Dr. Trowbridge is primarily a teacher, and a distinguished one. His long academic career from 1911 to 1952 was spent at the University of Iowa. As Professor Emeritus he has remained as active as ever in teaching, both at the University of Iowa and elsewhere, and more than one young geologist has become his student while he was on some assignment as a geological consultant. Anyone interested in listening to him discuss some geological problem will not only learn something new, but will also recognize in Dr. Trowbridge those particular characteristics of humility, wisdom, tolerance and understanding that mark the great teacher. It is no accident that his former students, as well as many others who have been associated with him, know him as "Trow." This is their way of expressing affection and respect for the man.

It is not surprising that Trow became a teacher. His father, Samuel Hoyt Trowbridge, was a professor of geology and paleontology at Pritchett College, and his mother, Julia Goodhue, was a teacher of English. Samuel met Julia in 1869 at Drew Ladies Seminary, where he was teaching mathematics and natural science and she was teaching English. They were married in 1871, and Arthur, the youngest of their six children, was born March 4, 1885 in Glasgow, Missouri. Arthur was only a year old when his father died, so he was denied the companionship that a boy so much needs in his early years.

After schooling at the Pritchett Institute and College, Arthur entered the University of Chicago and started on a premedical course. After two years, however, he came under the influence of Salisbury and Atwood and changed to geology. In the summer of 1905 he attended Atwood's field course at Baraboo, Wisconsin, where so many budding geology students from midwestern colleges and universities have had their first encounter with field geology. In 1907 he himself taught the same field course and continued for twenty more summers to lead students over the famous quartzite hills.

Trowbridge was graduated from the University of Chicago with a Bachelor of Science degree in 1907 and was granted a Doctoral degree in geology in 1911. The same year he commenced his teaching career at the Uni-

versity of Iowa, as professor of geology, and for 41 years taught geology to thousands of students, many of whom are now distinguished geologists. One of them, Gordon I. Atwater, prepared the citation for Dr. Trowbridge when he was elected an Honorary Member of the American Association of Petroleum Geologists,[1] and his remarks on that occasion have been most helpful in preparing this citation.

As an administrator, Dr. Trowbridge attained eminence in two quite different but closely related activities. In 1934 he was made head of the Department of Geology and during the next 18 years, before his retirement in 1952, he maintained this department at a highly respected level in American geology. Also in 1934 he became State Geologist and director of the Iowa Geological Survey, and for the next 13 years guided the work of that bureau. He left it in 1947, when he resigned, a revitalized and active organization with an annual budget more than 10 times as great as the one he started with in 1934. Such success with stubborn legislators bespeaks unusual ability to arouse interest, command respect, convince the skeptical and uninformed, and thus to influence people.

In spite of the heavy demands of his classes, and the responsibilities of a department head and a survey director, Trow still found time to carry on some research. Most of his fifty-some publications deal with sediments and sedimentary rocks, and in his biographies he lists himself as a "sedimentologist." He coined the term *sedimentology* for one of his several fields of specialization, and there was quite a spirited discussion at the time as to whether certain geologists should call themselves "sedimentationists" or "sedimentologists." Trow's term is now so widely accepted and used that it has become fixed in geological nomenclature.

For more than a decade he was a member of the Committee on Sedimentation of the National Research Council's Division of Geology and Geography, and he served as its Chairman from 1932 through 1935. Since retirement, Trow was for three years a geological consultant to the Sedimentology Unit of the Gulf Research and Development Company, conducting research on sediments in the Gulf of Mexico. His long interest in the valley of the Mississippi River and in the continental shelf of the Gulf of Mexico is represented by numerous published papers, and was the subject of his Vice-Presidential address before Section E of the American Association for the Advancement of Science at the Boston meeting on December 30, 1953.[2]

Arthur Carleton Trowbridge has rendered distinguished service to the earth sciences as professor, department head, survey director, research scientist, field investigator and geological consultant. In his half century of service he has been a constant inspiration to his students and professional associates, further stimulating the interest in geology that they themselves already had. He richly deserves the Neil Miner Award, and we of the Association are honored by being able to add his name to the growing list of distinguished men who thus far have been selected for this honor.

ROBERT R. SHROCK

REPORT OF THE SECRETARY, 1960

The paid-up membership of the Association stands today at 631, the highest in our history. When this figure is compared with 519 for 1959 and 468 for 1958, it will be seen that we have gained 112 members in the last year compared with a gain of 51 for the previous year.

An analysis of the membership of the various Sections shows that the Eastern Section is the largest, with 167 members. Special attention should be called to the two youngest Sections, which are far from the smallest. The Southwest Section, only a little over a year old, has 43 members, while the Texas Section, which has yet to celebrate its first birthday, has 67 names on its rolls and is the fourth largest in the Association. Both of these Sections are to be congratulated on the extremely fine showing that they have already made.

Once again I would like to express my appreciation for the splendid cooperation shown by the officers of both the National Association and the Sections, as well as by the chairmen of committees.

Respectfully submitted,
FREEMAN FOOTE, *Secretary*

[1] G. I. Atwater, 1959, "Arthur Carleton Trowbridge, Honorary Member," *Bull. Amer. Assoc. Petrol. Geol.*, vol. 43, pp. 1756-1758.

[2] A. C. Trowbridge, 1954, "Mississippi River and Gulf Coast Terraces and Sediments as Related to Pleistocene History—A Problem," *Bull. Geol. Soc. Amer.*, vol. 65, pp. 793-812.

MINUTES OF THE JOINT MEETING OF THE EXECUTIVE AND POLICY COMMITTEES, HELD IN DENVER, COLORADO ON NOVEMBER 1, 1960

Present for the Executive Committee Croneis, Campbell, Foote, Judson, Berg, Matthews (Texas), and Freas (Southwest). The Vice-President-elect, the Treasurer-elect, and the Editor also attended. *Present for the Policy Committee* Howland, Dorf, Behre, Peoples, Berg, and Foote. The Chairman of the Curriculum and Standards Committee was also present.

The meeting was called to order at 8 A. M. The minutes of the last meeting were approved as printed in Vol. 8, No. 1 of the *Journal of Geological Education*.

Chalmer Roy, chairman of the A.G.I. Education Committee, announced that the A.G.I. hoped to sponsor, with the aid of a grant from the N.S.F., a field seminar during the summer of 1961 to the British Isles for twenty young American geology teachers. The trip would be conducted by a leading British geologist and by Paul Shaffer of the University of Illinois. He asked N.A.G.T. to nominate three members to serve on a selection committee of five.

Roy also announced that A.G.I. hoped to receive an N.S.F. grant to undertake a two-year study of curricula and course content in geology in American colleges and universities. He said that a seven-man steering committee was contemplated, with twenty-one additional members to serve on a six-week summer conference. The program is to have a full-time, paid director. He asked N.A.G.T. to nominate five men for the steering committee. A general discussion of accrediting and accrediting agencies followed.

The Secretary reported on the election of National officers for 1961. He stated that exactly 300 ballots were returned. For President, Charles D. Campbell received 292 votes; five individuals received one vote each and three blank ballots were returned. For Vice-President, A. O. Woodford received 295 votes; three single votes were cast and two blank ballots returned. For Secretary, Dorothy J. Gore received 295 votes and again three single votes were cast and two blank ballots returned. For Treasurer, Wakefield Dort received 286 votes; eight scattered votes were cast and six blank ballots returned. The tally was approved and the new officers declared elected.

Charles D. Campbell was elected A.G.I. representative for a term of two years.

A. O. Woodford was designated N.A.G.T. representative on the G.S.A. 1961 Annual Meeting Program Committee. The Executive Committee voted that, as a matter of policy, this position would always be filled by the Vice-President, it being understood that he shall have the power to appoint an alternate if he is unable to attend a meeting.

The Secretary asked instructions in the handling of requests received for membership lists to be used for advertising purposes. It was unanimously voted that the Secretary be authorized to use his own discretion in the distribution of membership lists, but that, in general, it is not the policy of the Association to distribute these lists except for *bona fide* scientific purposes.

The Report of the Treasurer, which appears elsewhere in these Transactions, was read and approved.

The Editor reported that the Fall issue of the *Journal of Geological Education* would be mailed within the next few days. He said that there was no large backlog of papers awaiting publication. The possibility of the Journal being issued on a quarterly basis was discussed, and the hope was expressed that, as the membership grows, this will become possible.

The President reported that N.A.G.T. had become an affiliated society of the G.S.A. by action of the G.S.A. council at its May meetings. He then went on to discuss the relationship of the small and large colleges with N.A.G.T. He pointed out that the national meeting of N.A.G.T. must be as interesting as the sectional meetings if the Association is to be successful. He expressed the hope that the present trend in membership, which shows more and more teachers from large colleges and universities joining the organization, would continue until all geology teachers were in the Association.

The Vice-President discussed the difficulty of arranging programs in conjunction with the G.S.A. meetings because our interests cut across the entire field of geology. He pointed out that there is nothing regional in the interests of our Sections, in contrast to the interests of the sections of the G.S.A.

The Treasurer raised the possibility of combining the offices of the Secretary and the Treasurer. He stated that this would eliminate a considerable amount of duplication and that he felt that a small stipend should be paid the incumbent. Other members of the committee suggested that if the Secretary-Treasurer were to receive a stipend, the Editor should also. There was general agreement that if the offices of Secretary and Treasurer were combined, the term of office should be lengthened to five or six years. No action was taken on these suggestions.

Finally the Committee empowered the incoming President to make the nominations requested by the A.G.I., and suggested that members of the Curriculum and Standards Committee be considered for these nominations.

The meting was adjourned at 9 A. M.

Respectfully submitted,
FREEMAN FOOTE, *Secretary*

MINUTES OF THE BUSINESS SESSION, TENTH ANNUAL MEETING, NOVEMBER 2, 1960.

The meeting, held in Denver, Colorado, was called to order by President Croneis at 1:00 P.M. Eighty members were present. Before proceeding to the formal business of the meeting, the President introduced honorary members Leighton and Trowbridge, Past-Presidents Berg, Prouty, and Shrock, two former recipients of the Neil Miner Award, Behre and Woodford, and the Editor. He then asked Robert R. Shrock to present the 1960 winner of the Miner Award, Arthur Carleton Trowbridge. After Dr. Trowbridge had received the award and responded, the President asked Morris Leighton, one of the first of Dr. Trowbridge's students, to say a few words of appreciation.

The first item of business of the formal meeting was to approve the minutes of the last meeting, as printed in Vol. 8, No. 1 of the *Journal of Geological Education*. The President then outlined the year's activities of the Association, citing the formation of the Texas Section, the affiliation of the Association with the G.S.A., the increase in membership, our increasingly important position in A.G.I., and our sound financial position. He then announced that Glenn Stewart, University of New Hampshire, would be the chairman of the 1961 National Nominating Committee, and urged members to send any suggestions for nominees to him.

The Secretary reported the results of the election of National officers, as given in the minutes of the Executive Committee. The reports of the Secretary and Treasurer, which appear elsewhere in this issue, were read and approved.

The President then reported on the actions taken by the Executive and Policy Committees at their joint meeting the previous day. The election of members-at-large of the 1961 Neil Miner Award Committee followed. Erling Dorf was chosen the hold-over member; Raymond C. Gutschick and Robert W. Webb were elected new members. The statutory members of the committee are Charles D. Campbell, chairman, Cary Croneis, and Dorothy J. Gore.

Shrock called attention to the fact that the 1961 meetings of the Association would be held at Cincinnati, and suggested that it would be highly appropriate for the Association, together with the Paleontological Society, to conduct a symposium there devoted to the influence of the Cincinnati area on the teaching of paleontology. The President remarked that a similar suggestion had already been made to him by Norman Newell, the 1961 President of the Paleontological Society.

In conclusion the Editor pointed out that Neil A. Miner had been a student of A. C. Trowbridge, this year's recipient of the award bearing Miner's name. The meeting was adjourned at 1:50 P.M.

Respectfully submitted,
FREEMAN FOOTE, *Secretary*

Editor's note. The minutes of four sectional meetings follow. Those of the New England and Southwest sections were unavoidably omitted from the Fall 1960 issue, where they would normally have appeared. Those of the Pacific Northwest and Texas sections will appear regularly in the Spring issue, because these Sections hold their annual meetings and elect officers in December rather than in March or April.

NEW ENGLAND SECTION

The annual meeting of the New England Section was held on April 2, 1960, at Wellesley College, Wellesley, Massachusetts. Twenty-seven people were in attendance. Officers for 1960-61 were elected (see inside back cover).

"Bibliography of New England Geology" was the subject of a paper by the retiring President, Glenn Stewart. Other papers given were as follows: H. W. Borns, "Teaching Glacial Geology at University of Maine;" Wroe Wolfe, "Classification of Metamorphic Rocks;" Lawrence Goldthwait, "Geology at the Secondary-School Level;" R. R. Shrock, "Whence Come Our Teachers of Geology;" O. C. Farquhar, "Geological Societies in Great Britain;" and M. W. Bodine, "Problems of a One-Man Department."

MARSHALL SCHALK, *Secretary*

SOUTHWEST SECTION

The Southwest Section of the National Association of Geology Teachers held its first annual meeting on May 6 and 7, 1960, on the campus of Fort Lewis A. and M. College, in Durango, Colorado. The meeting was attended by 7 members of the Association and by about 15 industry geologists and high-school teachers from the Four Corners area.

After registration on Friday morning, May 6, the group left for a day-long field trip along the Animas River, to inspect rocks ranging in age from Tertiary to Precambrian. The excursion was under the leadership of Mr. Donald L. Baars of the Shell Oil Company.

Vice President Paul T. Miller presided at the annual business meeting, which was called to order on Saturday morning at 9:00 a. m. The Secretary-Treasurer presented a financial report for the year 1959-1960 and reported a balance of $30.76 in the treasury. Several members were concerned about the low attendance at the meeting. It was moved by A. J. Budding that the 1960-1961 executive committee of the Section be instructed to arrange the annual meeting in conjunction with a meeting of some other geological society in the Southwest region. The motion was seconded by F. O. Bowman and carried unanimously.

In view of the small number of members present, election of a new executive committee was postponed. It was moved by Clay T. Smith, and seconded by D. H. Freas, that a mail ballot, as presented by the nominating committee, with space for write-in candidates, and accompanied by a membership list, be sent out to the membership. This motion also carried unanimously. There being no further business, the business meeting was adjourned at 9:30 a. m.

The rest of the second day was devoted to panel discussions. The morning discussion dealt with the training of geologists for industry. Speakers from colleges and universities, as well as from oil companies, took part. In the afternoon a discussion was held on the desirability of adding geology to the high-school science curriculum. The opinion expressed by several speakers, representing different fields of the geologic profession, was that geology has its place in the high school, particularly since science in general has become of greater importance in the past few years. The meeting was concluded at 5.00 p. m.

A. J. BUDDING, *Secretary*

PACIFIC NORTHWEST SECTION

The annual meeting of the Pacific Northwest Section was held jointly with the Northwest Scientific Association at the University of Idaho, Moscow, on December 28-29, 1960.

The business meeting, held on December 29, was opened by Section President E. F. Cook, who gave his personal welcome to the group and made a few introductory remarks. A brief report was made by the Secretary-Treasurer, and Ewart Baldwin, chairman of the Nominating Committee, announced the slate of candidates for chapter offices. These candidates were unanimously elected (see inside back cover).

Charles Campbell, National President, was called upon to make a few remarks. He commented on the need for a new Section in the north-central area, on the suggested merging of the offices of National Secretary and Treasurer, and on the possible change of the *Journal of Geological Education* from semi-annual to quarterly publication. He also spoke of the Association's cooperation with the A.G.I. in recommending names of persons to serve on the N.S.F.-sponsored committee on curriculum and course content, and of persons for the panel that will select participants for the field seminar to be held in England this summer.

The afternoon program consisted of an informal seminar on polymetamorphic terranes of Washington and Idaho.

ERNEST H. LUND, *Secretary*

TEXAS SECTION

The annual meeting of the Texas Section was held in conjunction with the Texas Academy of Science sessions on December 2, 1960, on the campus of Texas Christian University at Fort Worth. A symposium on "Problems of Teaching Historical Geology" was the highlight of the meeting. William H. Matthews acted as moderator for a panel which consisted of W. C. Bell, John P. Brand, James W. Dixon, and Leo Hendricks. The papers and the open discussion promoted stimulating ideas, including suggestions for unconventional approaches to teaching historical geology. A synopsis of the ideas presented and discussed will be sent to all the members of the Texas Section. Other N.A.G.T. members may obtain copies by writing to the secretary of the Texas Section.

At the business meeting, which followed the symposium, the Section by-laws to the national constitution were approved. Appreciation was expressed to H. E. Eveland and his committee for their fine work in preparing the by-laws. The slate of officers for 1961 were then nominated and unanimously elected (see inside back cover).

Donald E. McGannon was elected Section representative on the national nominating committee for 1961. It was agreed that the Vice-President, who is program chairman for the next annual meeting, will be the representative to the Texas Academy of Science. This was done because the Section is an affiliate society of the Academy and their meetings are held jointly. The meeting of December 1961 will be in Galveston, Texas.

ROBERT E. BOYER, *Secretary*

SUMMARY REPORT OF THE TREASURER

Assets brought forward from 1959 fiscal year:			
Cash balance, Jan. 1, 1960		$1,597.46	
Horberg Fund savings bonds (purchase price)		325.50	
Income, 1960 fiscal year:			
Dues payments from Sections	$1,430.50		
Donation, East-Central Section	50.00		
Sales of the Journal	507.13		
Total income, 1960		1,987.63	
Total credits as of Dec. 31, 1960			$3,910.59
Expenditures, 1960 fiscal year:			
Journal of Geological Education	$1,285.37		
Officers' expenses	86.61		
Contribution to A.G.I. (10 percent of dues collected in 1959)	145.50		
Contribution to Texas Section	20.00		
Total expenditures			$1,537.48
Total cash and bonds on hand, Dec. 31, 1960			$2,373.11

Respectfully submitted,
SHELDON JUDSON, *Treasurer*

NATIONAL OFFICERS, 1961

President: Charles D. Campbell, *Washington State University*
Vice-President: A. O. Woodford, *Claremont, California*
Secretary: Dorothy J. Gore, *Principia College*
Treasurer: Wakefield Dort, Jr., *University of Kansas*

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Southwestern Louisiana Institute

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Lamar State College of Technology
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Editor: Richmond L. Bronaugh
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New Mexico Institute of Mining and Technology
Editor: A. J. Eardley
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University of Washington
Vice-Pres.: George A. Williams
University of Idaho
Sec.-Treas.: Marie Pabst
Western Washington College
Editor: George Koch
Oregon State College

CHAIRMEN OF N.A.G.T. STANDING COMMITTEES

Arthur L. Howland, *Policy*
Robert E. Boyer, *Membership*
Chilton E. Prouty, *Curriculum and Standards*
Glenn W. Stewart, *Nominating*

THE NATIONAL ASSOCIATION OF GEOLOGY TEACHERS was founded in the Middle West in 1938. In 1951 it became a national association, under which there are at present nine organized regional sections (see inside of this cover). An annual meeting of the national association is normally held in the fall, and most sectional meetings are held in the spring.

The purpose of the Association, as stated in its Constitution, is "to foster improvement in the teaching of the earth sciences at all levels of formal and informal instruction, to emphasize the cultural significance of the earth sciences, and to disseminate knowledge in this field to the general public."

Anyone concerned with geological education, formal or informal and at any age level, is invited to apply for membership. *Inquiries should be addressed to the national secretary,* DOROTHY J. GOSS, Principia College, Elsah, Illinois.

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